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Waste Paper Recycling A Community Technology Approach

Christine Thomas BSc

PhD thesis

May 1986

C O N T E N T S

WASTE PAPER RECYCLING : A COMMUNITY TECHNOLOGY APPROACH

Acknowledgements

Abstract

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P A R T I COMMUNITY TECHNOLOGY APPROACH TO RECLAMATION AND RECYCLING

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ABSTRACT

This research project aims to explore the hypothesis that a Community Technology approach can be considered appropriate for reclamation and recycling activities, and to investigate the opportunities for reclaiming and recycling domestic wastes viably at a 'community' scale. A framework is first established to define a Community Technology approach, and then used to assess the compatibility of reclamation and recycling technologies to this approach. 'Community'-scale reclamation and recycling in Britain, together with some examples from the USA, is examined and the 'state of the art' for both areas of activity described. 'Community'-scale is interpreted as relating to groups of people of less than 10,000, defined as neighbourhoods (of between 100 and 1,000 people) and communities (of 1,000 to 10,000 people).

Initial analysis identified only three recycling processes with potential as 'community'-scale activities; all concerned with waste paper recycling. One of these, a neighbourhood-scale technology, was chosen for a detailed feasibility study. The process involves recycling waste paper into sheets of drawing or printing paper suitable for use as 'art' paper, in particular as speciality printing paper, or as sugar paper in schools. The feasibility study was carried out using design and evaluation methods, to evaluate the technical and economic feasibility of the process and to investigate what role it might play in the community, in particular in relation to promoting greater community self-reliance. The results show that this technology would not be financially or economically viable as an independent enterprise but indicated additional non-quantified social benefits and hence a possible non-economic role in the community. Some possibilities of educational and job creation roles are explored.

INTRODUCTION

The main objective of this research project was to investigate the opportunities for reclaiming and recycling domestic wastes viably at a community scale, and to examine the hypothesis that a Community Technology approach can be considered appropriate to this range of activities. This objective was interpreted as being concerned not only with establishing criteria for assessing the appropriateness to a Community Technology approach of existing reclamation and recycling activities, but also with investigating the opportunities for developing new community-scale reclamation and recycling technologies.

This research project developed from research work undertaken by the author on the potential environmental benefits of reclamation and recycling activities, with particular reference to domestic wastes. This research included working with the Intermediate Technology Development Group on a preliminary assessment of the potential of small-scale paper recycling in Britain. At that time there was increasing interest amongst environmental and other community groups in promoting small-scale, community based recycling as an employment creating activity. However much of this interest was based on enthusiastic belief rather than detailed knowledge. This research project hence developed from the perceived need to substantiate or refute the claims being made for the potential offered by recycling technology to creating community-based, job-creating enterprises.

The hypothesis that a Community Technology approach can be considered appropriate to the reclamation and recycling of domestic wastes was examined in this research project on three different levels. The first

level explored the hypothesis in its broadest interpretation and considered the question of whether reclamation and recycling activities are compatible with the principles of Community Technology; ie, whether they comply with criteria such as not being exploitative of natural resources, and amenable to small-scale, decentralised development and control. The second level of examination more specifically assesses which reclamation and recycling technologies, if any, can be considered Community Technologies. Part I of this thesis is concerned with these first two levels of examination, and Part II with the third, and most specific level. This considered the technical and economic viability of establishing a particular community-scale reclamation and recycling activity. For reasons explained later, the particular activity chosen for this detailed examination was neighbourhood-scale paper recycling.

The method generally adopted in Part I of this thesis, due to the nature of the questions being asked in this part of the research project, and the scope of the subject involved, was that of desk research. This included examination of the available literature and correspondence, visits and interviews with individuals and organisations involved with community-scale reclamation and recycling projects. The information gathered was then assessed and summarised in order to address the two central questions being posed.

Chapter 1 deals with the question of what is meant by a Community Technology approach. It explores the literature on Community Technology and community self-reliance, and considers the role played in promoting the latter by community enterprises, with particular reference to community-scale recycling activities. Chapter 2 establishes

that recycling activities, where substituted for production from primary raw materials, result in environmental and social benefits thus demonstrating their appropriateness as Community Technologies. Chapter 2 also describes an economic framework for assessing these benefits. Chapter 3 describes briefly the current situation as regarding the disposal, reclamation and recycling of domestic refuse in Britain.

Chapters 4 and 5 provide accounts of community-scale reclamation and recycling activities respectively, with regard to the present 'state of the art'. These serve to highlight the lack of detailed information or analysis concerning the appropriateness of reclamation or recycling technologies to developing community scale enterprises. It would seem from Chapter 4 that more evidence is available concerning community based reclamation, in the form of source separation schemes, than of recycling activities. The dependence of community-scale reclamation schemes on available markets for the materials collected emphasises the importance of developing community-scale recycling schemes to provide these markets. Although the preliminary survey of existing community-scale recycling activities, described in Chapter 5, shows a significant amount of activity in repair, renovation and reuse, it reveals only a small number of recycling technologies, that might be considered appropriate to community-scale application. In some cases research and development were still being carried out, whereas in others the equipment and processes were already in use. Relating these recycling technologies to the size of the community likely to generate sufficient reclaimed material through a source separation scheme for them to operate, identified only three 'community' scale recycling technologies. All were concerned with recycling waste

paper, one operating at a neighbourhood-scale and the other two at a community-scale.

Chapter 6 provides an historic and technical background to paper and its manufacture. It also looks more closely at paper recycling, and at paper making in the British Paper and Board Industry, in order to examine the context in which community based paper recycling must fit.

Part II of this thesis, being concerned with testing the hypothesis that a Community Technology approach can be considered appropriate to the reclamation and recycling of domestic wastes at a more specific level, required a different research approach to that adopted in Part I. This part of the research project was undertaken using design and evaluation methods as a feasibility study of one particular reclamation or recycling technology. The basic approach adopted for this feasibility study involved carrying out a pilot study and subsequent evaluation study, in order to evaluate the technical and economic feasibility, as well as to explore what roles, social or economic, the recycling technology might play in the community. Neighbourhood-scale paper recycling was chosen, from the three community-scale recycling technologies identified, for this feasibility study, as the technology most accessible to this type of research project.

Chapter 7 introduces the research method followed by, the aims of, and the procedure adopted in, this feasibility study. Chapter 8 describes the results and analysis of the pilot study. The pilot study was based on the practical operation of the recycling technology in a community context in cooperation with the Milton Keynes Neighbourhood Care Youth Opportunities Programme scheme (a job-creation and community

service scheme for young unemployed people). Chapter 8 includes a technical evaluation of the Melbourne 5 plant (the equipment on which the proposed paper recycling enterprise was based) and records the product development and assessment, the preliminary financial analysis and preliminary marketing research carried out.

Chapter 9 details the evaluation report covering technical, production, financial and economic evaluation of the proposed enterprise.

Summarising and discussing the results of the pilot study, the main conclusion is that the proposed neighbourhood-scale recycling project would not be financially or economically viable. The evaluation report however does suggest that this project has a potential social benefit, and that a role may therefore exist for it in the community, which lies outside an economic role, for example as an educational or job creation project. Chapter 10 further explores this community context of the project, assessing both potential community involvement and appropriate scale of community.

Part III of this thesis attempts to relate the specific questions addressed in Part II to the wider issues discussed in Part I, and to place the conclusions reached in the feasibility study within this more theoretical framework. Experience gained through the feasibility study is used to reflect back on, and further question the concept of a Community Technology approach. In particular the feasibility study makes apparent certain conflicts between the different criteria defining a Community Technology approach, and the difficulties of assessing an appropriate scale for reclamation and recycling activities.

PART I

COMMUNITY TECHNOLOGY

APPROACH TO RECLAMATION AND RECYCLING

CHAPTER 1

COMMUNITY TECHNOLOGY

Community Technology is one approach developed as a response to, and as a critique of, contemporary industrial technological development. Other similar approaches include Alternative, Appropriate, Soft, Human-scale, Small-scale, Intermediate, Radical or Liberatory Technology, and Biotechnics. Often referred to as the 'Alternative' or 'Appropriate Technology Movement', they share elements of a common critique and common beliefs, but with each laying a different emphasis on different aspects. They are attempts to devise alternative forms of technology as a means to improving the social control of existing technology. This chapter explores the concept of Community Technology, and how it relates to issues of reclamation and recycling.

Criticism of technological development is not a recent phenomenon, with a history stretching back certainly as far as the early years of the Industrial Revolution. Nineteenth century social critics such as Robert Owen, William Morris and Peter Kropotkin (see Boyle (1978), Kropotkin (1974) and Morris (1970)) all condemned the direction and form social and technological change was taking, but who also pointed to an important potential role that technology could play in enabling a more liberated, egalitarian society to emerge. More recently Herbert Marcuse (1969), Ivan Illich (1973), Aldous Huxley (1947), David Dickson (1974) and Theodore Rosak (1974) have expressed a common belief that most of the problems associated with technological industrial societies are caused by the technological structure of that society, not just the form of political control; and that

alienation is inherent in forms of production created by technology developed to exploit and control people.

Dickson (1974) points to a growing distrust of contemporary technology, which has increased considerably in the past 20 years or so, as the benefits of technological development have been seen to be increasingly counterbalanced by the problems generated by its use. These include the manipulation and oppression of individuals, and the destruction of the natural environment, and the consistent failure to provide effective solutions to many world problems.

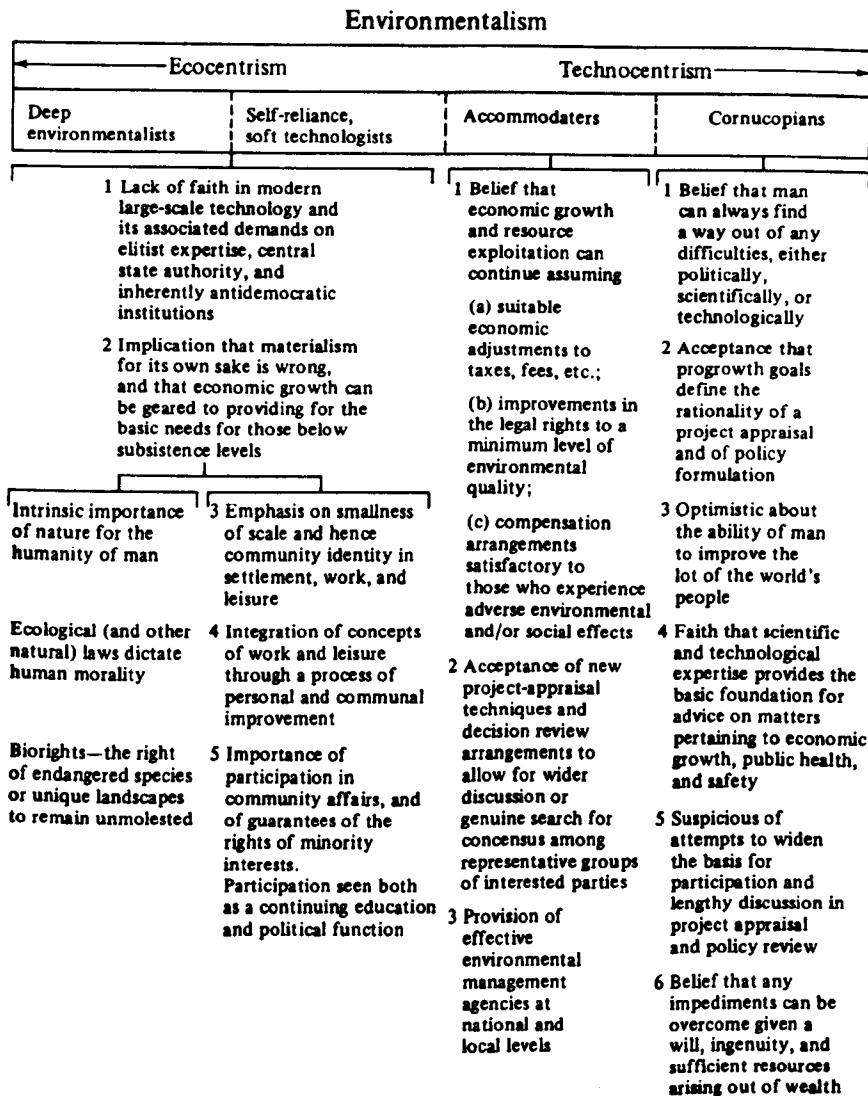
The environmental and ecology movement, which developed in the 1960s and 70s, has criticised contemporary technology heavily for its polluting effects, for depleting reserves of natural resources (including energy), and for destroying the natural habitats of many species of flora and fauna. Responses to 'correcting' or 'controlling' these detrimental effects of technology vary widely. O'Riordan (1981) categorises four such responses in what he describes as "a continuum of environmental concern". These represent, as Table 1.1 shows, the two divergent ideological themes that have evolved in environmentalism; the ecocentric and technocentric approaches.

Technocentrism, as defined by O'Riordan (1981) is identified by its optimism over its ability to successfully manipulate technology to solve problems of resource extraction and allocation; its determination to be value-free in both advice and analysis; its concern with rationality and managerial efficiency; its disavowal of widespread participation, and concern for control to be kept in the hands of

the 'experts'; and its disquieting fallibility, disquieting because technocentrists refuse to accept it. Technocentrists in general believe that 'technical fixes' can be devised to counterbalance or remove harmful environmental effects, although the degree to which they believe it varies, producing two types of technocentric response. The first, and most technocentric, is what has been called Cornucopian. Cornucopian's believe that all problems can be overcome by technical solutions, given commitment and political support. The second response comes from those who accommodate some of the ecocentric demands, recognising that some account should be given toward redistribution and environmental protection. O'Riordan (1981) argues that the western world predominantly lies in this technocentric accommodator mode at present.

The Ecocentrists, on the other hand, believe that no matter how much technocentrists accommodate, they cannot create a sustainable pattern of living. Ecocentrists are concerned that contemporary industrial technology and long-term environmental stability are not compatible. Ecocentrism is described by O'Riordan (1981) as providing a natural morality for environmentalism, "a set of rules for people's behaviour to be based on the limits and obligations imposed by natural ecosystems"; providing checks on the pursuit of progress; talking of limits of energy flows, productive capacity, costs of organisation and system maintenance; talking, in ecosystem metaphors, of permanence and stability, diversity, homeostasis and protection of options, used in relation to social and technical change; raising questions about ends and means, democracy, participation, distribution of power and wealth; and preaching to virtues of

FIGURE 1.1 THE PATTERN OF ENVIRONMENTALIST IDEOLOGIES.



Source: O'Riordan (1981)

self-reliance and self-sufficiency. Ecocentrists not only have a different attitude to nature from technocentrists, but also a different morality.

Ecocentrists can also be divided into two groups, described by O'Riordan (1981) and shown in Fig. 1.1 as the deep environmentalists and the soft-technologists. The deep environmentalists are the more ecocentric group, feeling most strongly the necessity for harmony with ecological processes and the sense of true association with the earth. The soft technologists although ecocentric, accept a more pragmatic approach, and concentrate their analysis on developing novel political and economic structures, involving major redistribution of power and resources, and changes in technological development. Sandbach (1980) refers to this attitude as anti-establishment environmentalism; one of the two types of environmentalism he describes which parallel the eccentric soft technologist and deep environmentalist ideologies. Anti-establishment environmentalists are principally concerned with people's alienation from society and from nature, and the causal relationship this has with science and technology. This has resulted in the Alternative/or Soft Technology response that the solution to environmental problems lie in the development of new non-alienating technologies. Environmental abuse is seen as a direct result of scientific and technological rationality, resulting in the control of nature being used to further technological progress or contribute to economic growth.

1.1 ALTERNATIVE TECHNOLOGY

Soft technologies or the 'Alternative Technology' movement, believe that social and political changes alone are not sufficient, and that new social and political structures with the same technology would not solve many of the problems encountered. Those involved in this movement are concerned to develop alternative technologies which would reflect different values and assumptions.

Many of these values and assumptions are held in common by the groups and individuals that make up this movement. Individually adopting a wide variety of names for their concepts (many of which are listed at the beginning of this Chapter) they each emphasise certain particular characteristics.

Various people have attempted to define these commonly held values and assumptions. Boyle and Harper (1976) summarised them as:

"A theory of technology and society which insists
that we can control technology, but if we don't it
will control us;
Recognition of physical and biological constraints
on human activity;
Social structure emphasising group autonomy and
control from the bottom up;
A bias towards simplicity and frugality in life and
technology wherever possible;
Preference for direct gratification in production
rather than through the medium of commodities;

An exploratory rather than a dogmatic application of the theory (such as it is...);
 Willingness to learn from unlikely sources such as 'primitive' cultures and technologies, 'mystical' experiences or abilities, and even liberal social theory."

Again Boyle (1978) cited the following criteria:

- "(a) a belief that conservation of the environment and of natural resources is vital to human survival;
- (b) a desire for as much independence from the centralized economy as possible by means of personal or local community self-sufficiency in basic needs (energy, shelter, food, etc);
- (c) general disaffection with existing social institutions, from a variety of political viewpoints;
- (d) a desire for 'meaning' in both personal relationships and at work;
- (e) the belief that small-scale technologies and institutions are more easily controlled to meet the needs of those directly affected by them;
- (f) a generally anti-materialist and anti-establishment outlook."

Harper (1973) uses these same values to argue for

"... a new science and a new technology; a new world view which would integrate objective knowledge with

subjective experience, reflect our dependency on the natural world, and incorporate the canons of the new eco-socialist morality; and a new array of tools and techniques that would:

Operate on low amounts of energy; not irreversibly disperse non-renewable resources; use local and easily accessible materials; recycle materials locally; not produce waste products at a greater rate than they could be absorbed by the natural cycling processes; not liberate novel chemical compounds in more than trace amounts; fit in with existing culture patterns; satisfy those who operate it; lend itself to control by those who operate it; have safeguards against misuse."

Expressing the same values and assumptions, Bereano (1976) adopts as a definition of 'Alternative Technology' that it should aim to make life better and easier by assisting humanity to overcome the constraints of scarcity, and yet be human-scaled and comprehensible; consistent with ecological processes; durable; less alienating than the dominant technological forms in industrial capitalism; less disruptive of the social psychological and cultural fabric; and reinforce, and be reinforced by, decentralised organisational structures.

Robin Clarke drafted a comprehensive list of characteristics to represent what he called 'soft' technology, again based on these

same values and assumptions, and contrasted them with the characteristics of 'hard' or conventional technology. These are listed in Table 1.1.

These characteristics generally focus on ecological (eg non-polluting, and non-exploitive of nature) and social aspects (eg accessible to control, non-exploitive of people). Clarke does not place a great deal of emphasis on political analysis, implying that technological change is of prime importance, and other changes will follow. This is a view often expressed by proponents of alternative technology, including Schumacher (1973) and the New Alchemy Institute (undated).

Others believe, as does Dickson (1974) that "while an alternative technology... may well be a necessary prerequisite for creating a non-alienating, non-exploitive way of life, the development of such a technology is not, I maintain, sufficient to ensure that this state of affairs will be brought about". He continues to argue that an alternative technology can only be developed within a social/political framework. A view strongly shared by Entemann et al. (1977), and the proponents of Radical, Community, and Liberatory Technologies.

1.2 COMMUNITY TECHNOLOGY

Community Technology shares the basic values and assumptions associated with all alternative technologies, but differs from other approaches in its emphasis on the importance of community control of

Table 1.1 CLARKE'S CHARACTERISTICS OF 'HARD' AND 'SOFT' TECHNOLOGY

	'Hard' technology society	'Soft' technology society
1	ecologically unsound	ecologically sound
2	large energy input	small energy input
3	high pollution rate	low or no pollution rate
4	non-reversible use of materials and energy sources	reversible material and energy sources only
5	functional for limited time only	functional for all time
6	mass production	craft industry
7	high specialization	low specialization
8	nuclear family	communal units
9	city emphasis	village emphasis
10	alienation from nature	integration with nature
11	consensus politics	democratic politics
12	technical boundaries set by wealth	technical boundaries set by nature
13	world wide trade	local bartering
14	destructive of local culture	compatible with local culture
15	technology liable to misuse	safeguards against misuse
16	highly destructive to other species	dependent on well-being of other species
17	innovation regulated by profit and war	innovation regulated by need
18	growth-orientated economy	steady-state economy

19	capital intensive	labour intensive
20	alienates young and old	integrates young and old
21	centralist	decentralist
22	general efficiency increases with size	general efficiency increases with smallness
23	operating modes too complicated for general comprehension	operating modes understandable by all
24	technological accidents frequent and serious	technological accidents few and unimportant
25	singular solutions to technical and social problems	diverse solutions to technical and social problems
26	agricultural emphasis on monoculture	agricultural emphasis on diversity
27	quantity criteria highly valued	quality criteria highly valued
28	food production specialized industry	food production shared by all
29	work undertaken primarily for income	work undertaken primarily for satisfaction
30	small units totally dependent on others	small units self-sufficient
31	science and technology alienated from culture	science and technology integrated with culture
32	science and technology performed by specialist elites	science and technology performed by all
33	strong work/leisure distinction	weak or non-existent work leisure distinction
34	high unemployment	(concept not valid)
35	technical goals valid for only a small proportion of the globe for a finite time	technical goals valid 'for all men for all time'

Source: Dickson (1974)

technology, and in that technology serving the needs of a small community. Boyle (1978) defines Community Technology as:

"'Community technology' denotes a range of tools and techniques that in general conform as far as possible to Robin Clarke's criteria for 'soft' technology and in particular are designed to serve the needs of, and to be amenable to direct democratic control by, the citizens of a small community occupying a specific geographical area."

Another description is provided by Community Technology Inc. a group established in 1973 in Washington DC, USA; again quoted in Boyle (1978):

"'Technology' the group felt 'is too often seen as a vast, mysterious force beyond the control of ordinary humans. Its vastness is tolerated because of imagined economies of scale; the mystery remains unchallenged because of its remoteness from everyday life. It thus becomes master rather than servant, repressive rather than liberatory, cumbersome and impersonal rather than versatile and humane, tending always to proliferate and pollute.' Community Technology, on the other hand, stressed that it was a contrasting view of technology 'in which science is demystified and put to work on a smaller, more human scale. Here technology is under the direct control of the people whose toil it replaces and whose community it helps make self-reliant - an organ of an organic social grouping. It tends to be environmentally benign, relying mainly on local and renewable resources.'"

Morris and Hess (1975) stress the importance of Community (Neighbourhood) Technology and production to the development of community power, and in building productive self-governing units. They do not suggest that communities become completely self-sufficient units, but rather that in order to gain greater political control on a local basis they require greater economic control and in turn greater control of production (ie Community Technology). This theme of increasing local self-reliance, and of producing from locally available resources goods to satisfy local needs, is an important factor in Community Technology.

1.2.1 What is meant by Community?

In discussions of Community Technology rarely is there any attempt to define the term community, except by reference to general terms such as human-scale and local, and a belief that communities should be small. The latter derives from a concern that the smaller the community (whether in area or population), the greater the ability of individuals to participate fully in the democratic control of their lives.

Schumacher (1975) is similarly non-exact in the following definition of what he means by small-scale as "the order of size or scale which the mind can encompass". Boyle (1978) however provides a much more precise and clear definition of what he defines community, as related to Community Technology, to be...

"The 'community' to which community technologists aspire would therefore be likely to have a population of a few thousand, up to a maximum of 10,000 or so (ie a population of the 'order of magnitude' of 1,000). Such a community might plausibly be subdivided into 'neighbourhoods' with populations of a few hundred up to about 1,000 (ie of 'order of magnitude' of 100). It might also be further subdivided into informal groups of dwellings, each with a population of up to about 100 (ie of the 'order of magnitude' 10), in which the inhabitants might form a 'circle' of close neighbours or intimate friends. (Please note carefully here that my assignment of numbers in ascending orders of magnitude is not meant to be a statement of the precise size of each social unit, which would of course vary widely in practice...)"

A community of this size would itself be part of larger political units, which Boyle (1978) goes on to define as the district level (order of magnitude 10,000) with a population of up to 100,000; the county level (order of magnitude 100,000 with a population of up to one million; the regional level (order of magnitude 1 million) with a population of up to 10 million; and the national level (order of magnitude 10 million) with a population of 56 million in the case of the UK.

This classification is used throughout this thesis, and further provides the definition of community adopted. The 'community' to which Community Technology refers is interpreted as a group of

people of less than 10,000; that is a community, neighbourhood or group of dwellings in the Boyle classification. To distinguish between community as defined by Boyle, and the broader definition adopted in this work, the latter will be used in inverted commas.

1.3 COMMUNITY TECHNOLOGY APPROACH TO RECLAMATION AND RECYCLING

Reclamation and recycling are a group of activities which have found support from many sources, including the wide spectrum of environmental thought from ecocentrism to technocentrism. In particular the technocentric accommodator and the alternative-technology ecocentric approaches in environmentalism have showed a specific interest in reclamation although they differ in their approaches, justification and the scope of reclamation activities each proposes.

The concern to develop a technology that is not destructive of the environment is a common theme to both the accommodator and alternative technology approaches. Reclamation and recycling activities in general result (as demonstrated in Chapter 2) in environmental impact benefits when compared to production from virgin raw materials.

Although often in agreement over the desirability of specific reclamation activities, the alternative technology approach often conflicts with the accommodator approach in respect of the extent of reclamation considered desirable. Accommodators tend to take the traditional decision criteria of financial and economic viability as their measure of desirability, using political and technological assessment techniques such as cost-benefit analysis. Thus taking

some account of social desirability but only in terms of economic efficiency criteria. Alternative technologists argue that a wider definition of social desirability is required; one that takes into consideration the concerns of environmental ethics or bioethics, as well as other social concerns such as equity, exploitation, alienation and the "quality of life". Some overlap between the alternative technologist and accommodator approaches exists and is demonstrated in some of the attempts to extend the technocentrist technique of cost-benefit analysis to account for environmental ethic concerns, such as the future availability of resources and effects on ecological diversity (see Chapter 2 for further discussion of how cost benefit analysis can be modified to include these and other aspects of environmental concern). However, the accommodator approach is not in general so concerned with those wider, more intangible environmental and social effects of technological development, as it is with economic efficiency and growth. On the other hand, the alternative technology approach sees this concern with economic growth as "incompatible with environmental quality, basic human needs, social equity, humane values, and the quality of life" (Morrison, 1980).

The accommodator approach sees in reclamation an opportunity to achieve a technical fix which is environmentally beneficial, doesn't challenge the direction of conventional technological development or require a radical socio-political change, challenge economic growth or necessitate reduced resource exploitation. O'Riordan (1981) comments that:

"...energy conservation, recycling technologies, and pollution-control developments are now regarded as generators of economic growth into which the smarter entrepreneurs are moving with taxpayer subsidised support."

This 'technical fix' is often also seen as an opportunity to create jobs which benefit rather than destroy our environment.

Friends of the Earth have been advocating the development of environmentally sound technologies (including waste recycling) for many years. Green and Webb (1977) maintain that through such technologies "the application of environmental principles can meet real social and economic needs within the community and in the process creates new jobs". In a more recent publication, Barbier (1981) considers the employment potential of four environmental policies; loft insulation, paper recycling, cycle way construction and an allotments programme. He concludes that:

"The employment creation potential of the environmental policies described, and their revitalising efforts on the various industries concerned, make them essential in a time of economic recession and overall industrial decline."

The development of reclamation and recycling activities has in fact been repeatedly proposed to create and help alleviate high unemployment. For example Martin Timbrell (1980), in a discussion of Government action to alleviate high unemployment, stated that:

"Local authorities should have access to agreed sums of Government subsidy for each job created in... waste reclamation."

The alternative technology approach offers a somewhat different perspective; for whilst on one level agreeing with the activities of the technical fix, accommodator approach in respect of the potential environmental and employment benefits, on another level sees opportunities through reclamation activities to more radically challenge the status quo. The alternative technology movement has predominantly placed reclamation in the wider context of reducing unnecessary waste of both energy and material resources, and sees reclamation as an opportunity to challenge this wasteful ethic (Boyle and Harper, 1976; Hayes, 1978; Thomas, 1979) and confront issues of equity (Schnaiberg, 1980). Parallels are often drawn with natural cycles which are closed systems where everything is recycled, bringing out the ecological connections of this movement.

Reclamation is often seized upon by the alternative technology movement as an opportunity to develop appropriate technologies. Davis (1978) includes the principles of reclamation in his list of objectives for appropriate technology, and a wide range of reclamation and recycling activities are highlighted as special opportunities for small businesses. These cover repair and renovation, reclamation, recycling and re-use. The Socialist Environment and Resources Association (SERA) (1976) quotes a list of categories for 'appropriate' manufacturing industry, compiled by the Intermediate Technology Development Group (ITDG). This includes waste material separation and reprocessing, second life durables (ie repair, renovation and

manufacture from used components) and waste material processing for energy production.

Community technology with its emphasis on technology being appropriate to the need of, and in the control of, small communities, considers reclamation to offer opportunities to develop community technologies which will contribute to increasing community self-reliance.

Seldman (1978) maintains that recycling has an integral role to play in the development of self-reliant communities:

"...resource availability will reflect our ability to have an open, democratic society or one centrally managed through resource allocation... the more we close the loop to waste generation and the reprocessing of new products the closer we are to self-reliant communities."

Recycling within the community can make resources available to that community, bringing it closer to self-reliance. Seldman goes on to suggest that with increased recycling..."communities can supply the basics of a sound, environmentally safe, economy; and this is one of the major implications of the low-technology approach (to recycling)". The benefit of a community (or neighbourhood) being not only a social unit but a productive and self-governing unit are discussed by Morris and Hess (1975) who consider that the awareness of the community (neighbourhood) as an economic entity plays an important role in increasing political power of the community. Seldman (1975) suggests recycling as one economic activity to achieve this:

"Though the political economy of garbage might seem an unlikely subject, waste might nevertheless be a real catalyst in moving local communities towards a rebirth of local government."

Other sources also emphasise the suitability of reclamation activities to community-scale development.

Newman (1980), in the report 'Community Enterprise', written as part of the Trinational Inner Cities Project, concluded that "Community-based enterprises, combining refurbishment and recycling activities could be established in every community in Britain".

It is also often argued that the environmental impact benefits of community based, decentralised reclamation and recycling activities would be greater than those for some centralised, large-scale recycling operations. The dispersed nature of waste materials itself is a rationale for developing decentralised, community reclamation and recycling activities. In particular since this would reduce transport requirements and hence lessen the adverse environmental effects of transport due to polluting emissions and energy use.

CHAPTER 2THE ENVIRONMENTAL IMPACT OF RECLAMATION AND RECYCLING

Reclamation and recycling are complementary activities. Reclamation refers to the process of making a product which has come to be considered as waste available for further use; its processing for further use is known as recycling.

The form which the item will take after being reprocessed may be similar or markedly dissimilar to its original use. Recycling covers a very diverse range of processes, including the repulping of waste paper to make new paper, the use of broken glass in road surfacing, and pyrolysis - a process which converts plastics and organic wastes into liquid and gaseous fuels. These examples illustrate the three distinct classes into which recycling techniques are often divided; direct and indirect recycling and energy recovery respectively.

Direct recycling can be carried out internally within an industrial plant, where spoilt products (eg broken bottles) are fed back into the manufacturing process. It also refers to waste materials reclaimed after being further processed or used (eg broken bottles from a bottle-washing plant of a dairy) and returned for recycling into the same or similar product.

Indirect recycling and energy recovery are usually carried out if the waste material reclaimed is not of sufficient quality or value to make direct recycling worthwhile. That is if the material in question is contaminated with other materials, or simply that there is an insufficient market for the material for direct recycling.

Reclamation is generally understood to be a collection, sorting and storage operation, involving only that processing required to assist transportation and handling of the materials. Reclamation and recycling are not always distinguished as separate activities and often described together as reclamation activities. (This generic use of the term reclamation will occasionally be used in this thesis.)

Industrial products are not the only wastes to be reclaimed and recycled. Natural cycles themselves recycle carbon, oxygen, nitrogen, water and many other substances. Each cycle is composed of a number of different steps and overall, each cycle can be regarded as a 'closed' system for any particular material, a system in which none of the material is lost.

In contrast most industrial processes are 'open' systems. Raw materials are extracted, processed, used and discarded as waste. Reclamation and recycling attempts to close this loop by returning waste to the processing stage; however, there are limitations that make 100% reclamation of industrial wastes impossible. In particular, growth in consumption, energy limitations and even some physical laws put an upper limit on the proportion of materials that can be reclaimed. These limitations to reclamation are often compounded by many of the domestic and industrial practices which our society has evolved.

Industrial processes take a resource from a dispersed state, refine and process it with energy inputs and thus increase its concentration. The industrial process then proceeds by product design to combine this concentrated material with many other materials, and to distribute the

resultant products throughout the country and even the world. By so doing, resources become even more dispersed than they originally were.

Combining materials together, particularly in small quantities, makes reclamation difficult as it is energy expensive to reverse the process and to recover any one material. Often product design, being the result of concern to fulfill the designed function at minimum cost, and not the future recyclability of the product, does involve the use of many materials in intricate and complex combinations. Henstock (1983) discusses this and the substitution of materials with an established scrap market by those with little recyclable value, in relation to the problems that these inappropriate design practises create for reclamation and recycling. Wide distribution networks that have no reverse flow are similarly energy-expensive to correct.

It is important to distinguish clearly between material and energy resources, for while materials can be recycled, energy cannot. Energy is used at every step of every process in the initial manufacture of a product from its raw materials, and further inputs of energy are required later to recycle it into a new product. However, since it is often the case that less energy is needed to manufacture a product from reclaimed rather than raw materials, recycling can result in energy savings.

In the past 10 years or so, due to an increasing awareness of environmental issues, reclamation and recycling of waste materials has come to receive greater attention and interest. Two issues have focussed attention on reclamation and recycling; first the

concern that consumption levels of certain resources are high enough to cause doubt about their continued availability in the future. Considerable debate and controversy has surrounded this "Limits to Growth" question (see Meadows, 1972). In reviewing opinion on resource availability issues, Brobst (1979) concluded that:

"The stage is set for controversy about resource use and policy between the extremes of the catastrophists, who foresee the death of our industrial society because of resource shortages, and the cornucopians, who foresee virtually no problems with resources that technology cannot overcome."

Much of the debate however has focussed on the extent of depletion and predicted 'limits' to reserves, not actually questioning the validity, just the extent of resource conservation required. As Brobst (1979) states:

"although the earth is not going to run out of mineral resources on a given day, the physical constraints of geologic and economic availability do place limits upon which of them can be useful to our needs in the foreseeable future."

The second issue concerns environmental quality, its erosion due to increasing consumption of energy and goods, and its maintenance through the satisfactory disposal of waste materials.

Whilst reclamation and recycling of waste materials contributes towards resource conservation, they are certainly not absolute

solutions to resource scarcity. In a situation of increasing raw material consumption (which is that aspired to, if not realised in recent years) reclamation and recycling can only 'buy time' by helping to slow down the depletion of raw material reserves of non-renewable resources. The fundamental issue of resource scarcity concerns the desirability of a 'growth' economy involving increased growth in the production of consumer goods which themselves constitute waste in a short time. To tackle resource scarcity it is essential to investigate ways of reducing waste at source.

Unnecessary waste of resources is a difficult concept to define, but might be judged as that which might otherwise be avoided by changes in the design or distribution of a product, or in consumption patterns. The design of products plays an important role here; particularly in relation to the durability of a product.

Shorter product lifetimes can be encouraged by built-in obsolescence whether this arises as a result of a deliberate policy of the manufacturer to ensure that its products wear out quicker than they might or whether the products are designed in such a way that their repair becomes impossible. Premature obsolescence can also result from failures in the spare-part market and the inadequate provision of after sales service.

There are a number of other ways in which design can play an important role in creating or preventing unnecessary waste. Many products can be designed either for once only or for multiple use or reuse. Unnecessary waste can result from the overspecification of quality in certain products. This may be the result of poor design where

material, which could be substituted by a more abundant or environmentally less damaging resource, is used. For example, for a number of uses chemically-pulped papers are employed where a mechanically-pulped paper of poorer quality could be substituted. In the production of a similar quality paper, mechanical pulping generally consumes fewer trees, requires less energy and water and generates less pollution than chemical pulping.

However the design of products is not the only cause of excessive consumption. Consumer attitudes and preferences also play an important role. Overspecification in the design of a product may be the result of proven or imagined consumer preferences and, conversely consumer preferences may themselves be developed by the advertising and marketing of particular designs. It is hence often difficult to dissociate cause from effect.

Reducing unnecessary waste of resources, and unnecessary production of consumer goods is considered desirable also in relation to reducing the adverse effects on environmental quality caused, in many instances, by their production and consumption. The effect on environmental quality of any production process or resource-use policy is a complex matter, involving many interrelated factors. These may include air and water borne polluting emissions, raw material and energy consumption, solid and liquid wastes produced, water use, noise pollution, visual amenity, and effects on flora and fauna. Measuring and assessing such complex and diverse environmental impacts presents considerable problems. Environmental impact analysis (EIA) has developed as a conceptual framework to address these problems. EIA attempts to identify environmental impacts arising or likely to arise

from a proposed 'project', to assess and evaluate each, and to provide an overall aggregate evaluation of the range of environmental impacts. It is this latter area of aggregate evaluation of a number of impacts considered together which presents most difficulty in EIA. Catlow and Thirwell (1977) consider methods for achieving this; CBA, Ordinal ranking schemes, Value scores and Normalised values linked to objective measures. The last three all rely heavily on subjective evaluation of the relative value of different environmental impacts, and are less commonly used than CBA. CBA aims to compare different environmental impacts by calculating a monetary value for the social cost or benefit. CBA itself has many disadvantages in its use in EIA. However, it can be argued that it offers the best approach, particularly if those impacts which are omitted from the economic analysis are presented alongside it. A fuller discussion of the use of CBA as an analytical framework for assessing the environmental impact of reclamation and recycling options is included in Section 2.1.

The different effects on environmental quality generated by different resource-use practices has led to a specific interest in reclamation and recycling. Research that has been undertaken into the environmental impact effects of reclamation and recycling indicates, in general, that reclamation and recycling activities, where these substitute for production from virgin raw materials, can contribute to improvements in environmental quality. For example the US Environmental Protection Agency (1974) came to this conclusion:

"Enough is known about the relationships involved to indicate that the net national environmental effects will be beneficial in virtually all instances where resource

recovery (reclamation and recycling) is concerned and beneficial almost by definition for source reduction (reduction of waste at source)" (my brackets)

One of the benefits of reducing materials waste by reclamation is obvious. Total quantities of wastes arising are not affected by reclamation and recycling programmes, but those requiring disposal can be significantly reduced, and the disposal of increasing volumes of wastes presents contemporary industrial societies with a sizeable problem. In addition, the recycling of reclaimed materials will in many cases result in substantially less polluting discharges than the processing of virgin raw materials, and will lessen the environmental degradation and loss of amenity associated with raw materials extraction.

The remainder of this section discusses Cost Benefit Analysis as an analytical framework for assessing the environmental impact of reclamation and recycling and explores further the relationship between recycling and environmental quality. Specific examples of the environmental impact of recycling in respect of resource use, energy consumption and pollution levels are also considered.

2.1 COST BENEFIT ANALYSIS AND E.I.A.

"Cost-benefit analysis purports to measure in money terms all the benefits and all the costs to be expected over the future of some mooted project, and to admit the project if the sum of the benefits exceeds the sum of the costs by a sufficient margin." Mishan (1970)

It is the objective of attempting to 'put a price' on everything that has been differently interpreted as both CBA's strength and attractiveness as an analytical framework, and its weakness and focus of much of its criticism. Cost benefit analysis attempts to extend the framework of financial appraisal of projects to provide an economic appraisal, evaluating social costs and benefits in terms of their monetary value, and hence generating a single measure of the desirability of a project. Central to the concept of CBA is the method by which social cost and benefits are measured and compared. This is most commonly achieved using the potential Pareto improvement criterion. Sugden and Williams (1978) describe this criterion as follows:

"...a project provides a potential Pareto improvement if the total sum of money that the gainers from the project would be prepared to pay to ensure that the project were undertaken exceeds the total sum of money that the losers from it would accept as compensation for putting up with it."

The potential Pareto improvement criterion can also be described as providing a measure of the economic efficiency. Economic efficiency has been considered an attractive concept due to the degree of precision it purports to allow. However, particularly where CBA is extended to incorporate environmental impacts (ie in the form that it can be used in EIA) controversy surrounds how monetary values are assigned to social costs or benefits which do not have a market value. How to value, for example health, amenity, environmental quality, noise and safety presents CBA with immense problems.

However, CBA has evolved a number of techniques which attempt to value these intangible social costs and benefits. These include shadow pricing, where an indirect calculation of value is used in place of a direct market price, and proxy or surrogate values, where a shadow price is unknown. Many environmental impacts fall into this latter category, and Turner (1979) describes a variety of techniques which can be used to evaluate their value. These include survey or questionnaire methods to gauge willingness to pay or compensation; by observing consumer behaviour, such as for example the amount people are willing to pay to travel for certain amenities; and the 'hedonic' pricing approach which uses changes in property and land values to deduce a proxy value of the shadow price.

Through the use of these techniques CBA has been able to value some environmental impacts, although others continue to defy quantification in monetary terms. For example how to value ecological diversity and conservation of habitats; how to account for irreversible environmental effects, which brings in the question of evaluating risk; and how to value intergenerational equity, that is considering the environmental costs and benefits for future generations. Obviously values can be attached to all these intangible effects; for example, one method developed to enable monetary values to be attached to the concept of protecting ecological diversity and conservation of natural areas uses discounting with specially weighted interest rates to reflect the uniqueness and irreplaceability of such areas (O'Riordan 1981). However, there is no consensus on how this should be done, and on what monetary prices should be attached to the social value of these effects. Nash et al. (1975) argue that the underlying objectives of CBA must reflect some set of value judgements which determine what

effects should be regarded as benefits and what effects as costs. Making these value judgements more explicit, a number of approaches have been developed, adapting CBA to attempt to account for these "non financial efficiency" criteria.

How CBA accounts for environmental impact effects of a project depends both on how these impacts are separately valued and how a range of impacts considered together are aggregately evaluated. Approaches to the former are described above, and in respect of the latter Sugden and Williams (1978) describe two broad approaches: the Paretian approach (referred otherwise to as 'formal CBA' by Turner 1979) and the decision-making approach. Formal CBA concentrates on measuring economic efficiency, arguing that a project should go ahead if it leads to an increase in economic efficiency, and gives only secondary attention, if any, to those effects which cannot be assigned a monetary value. Sugden and Williams (1978) describe the decision-making approach as exploring wider social objectives than just economic efficiency, with reference to the objectives chosen by the decision-maker. Turner (1979) discusses a variety of approaches to decision-making CBA. All use economic efficiency criteria for those costs and benefits which can be assigned monetary values, but vary in their approach to incorporating an assessment of intangible environmental impact effects. One approach uses weighted values to give a single valued measure of benefits and assesses these weightings either by consultation with decision-makers or based on analysis of decision-maker's priorities. This has the disadvantage that the highly subjective value weightings of the decision-makers become quantified and hence given a deceptive objective status in the final CBA. Another approach involves disaggregating different objectives,

and performing and presenting separate evaluations, leaving the policy-maker to resolve conflicting objectives. In this broader context CBA becomes a form of policy analysis, providing a conceptual framework for relating resources to objectives, ordering information and informing individuals of the range of objectives.

This brief summary and critique of CBA attempts to show how the environmental impacts of a recycling option can be assessed by Environmental Impact Analysis using the conceptual and analytical framework of Cost-Benefit Analysis. In conclusion, there are a wide variety of CBA techniques available which could be appropriate to this type of analysis, although formal CBA has limited value in EIA. Of the various decision-making approaches to CBA, the disaggregated policy analysis format probably offers the best approach, due to the difficulties encountered in assessing value-weightings in order to provide the single-measure evaluation required by the other approaches.

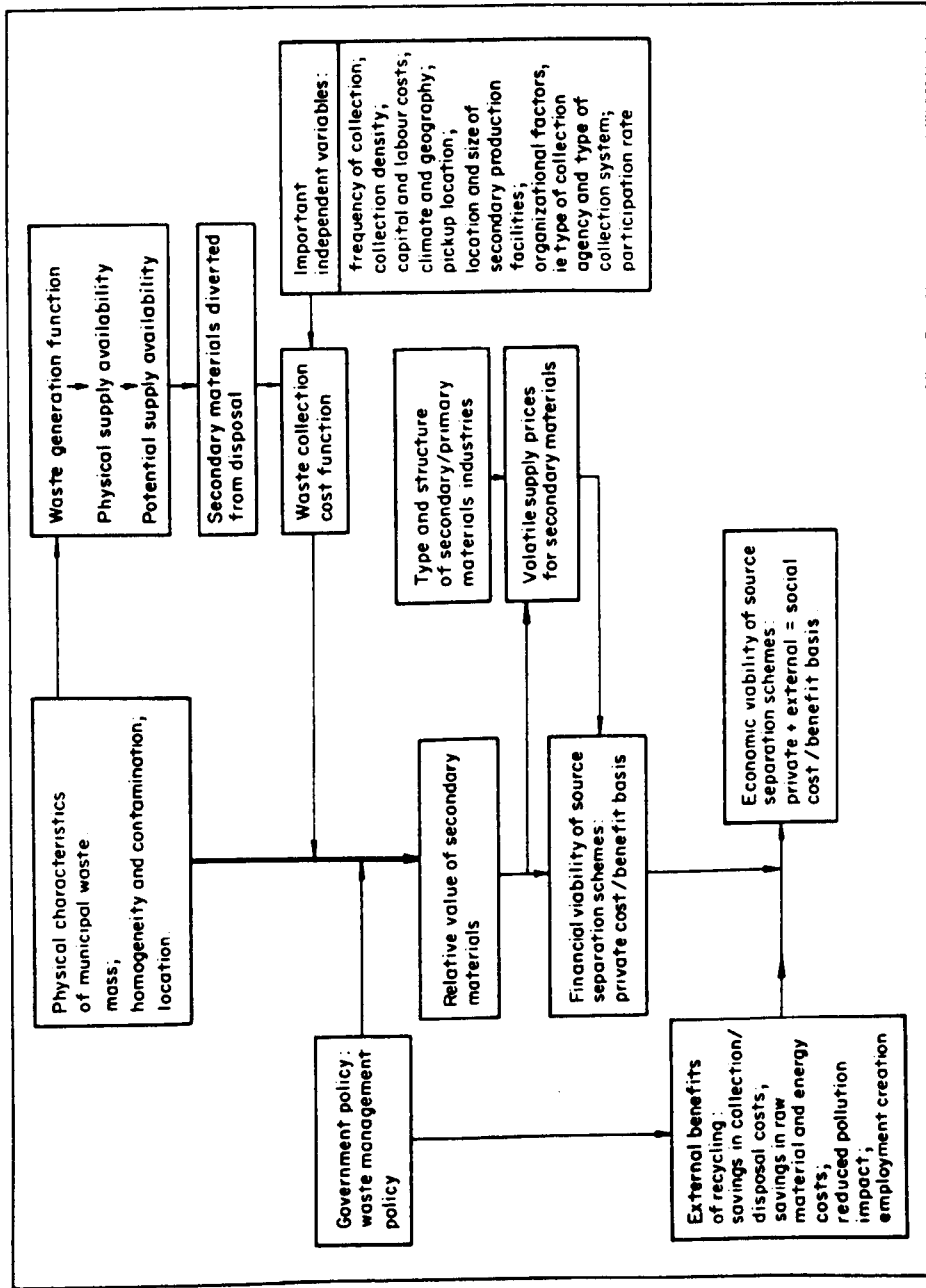
Turner (1979) argues that the disaggregated policy format CBA (or policy analysis) can be a useful decision making tool, and is better able to deal with non-efficiency criteria than other forms of CBA. Factors such as those mentioned earlier including the value of ecological habits, the irreversibility of some forms of damage to the environment and intergenerational choice and equity concerning resource depletion and pollution impacts (see Page, 1977) are difficult to value in money terms, and it is argued are better presented, as separately argued objectives.

2.2 ECONOMIC FRAMEWORK FOR RECLAMATION AND RECYCLING

Environmental impact analysis is only a part of an overall evaluation of a recycling project or option. A full appraisal of the social desirability of any recycling option should consider its financial viability, environmental impact and other social costs, and benefits. These factors can all be evaluated using the analytical and conceptual framework of cost benefit analysis. Turner (see Turner 1981), Turner and Thomas (1982) and OECD (1983) has developed an accounting or economic framework to enable judgements to be made of the social desirability of reclamation and recycling options. Based on CBA techniques, the framework determines social desirability in the first instance by economic efficiency criterion, evaluating both financial viability (i.e. private costs and benefits) and the wider external costs and benefits, including social and environmental impacts (see Fig. 2.1). Turner (1981) also considers, within his economic framework for recycling schemes some of the limitations of the economic efficiency criterion as the sole measure of social desirability. In order for full account to be taken of social impacts, including environmental impacts, of recycling options, then an economic framework for reclamation and recycling should also accommodate discussion where possible of the effects of intangible environmental impacts separately argued and presented alongside the economic efficiency analysis; thus combining both the economic efficiency criterion and disaggregated policy analysis format of CBA.

All reclamation and recycling schemes have financial costs and benefits associated with the costs of collection or purchase of reclaimed material or product. These inputs into the financial

FIGURE 2.1 SOCIAL COST-BENEFIT APPROACH TO RECLAMATION AND RECYCLING SCHEMES



Source: Turner and Thomas (1981)

viability equation depend on a number of variables, which are summarised in Fig. 2.1. Turner (1981) examines the relationship between financial viability of reclamation and recycling schemes and each of the "important independent variables" shown in this diagram in some detail and attempts to quantify these where possible. Other factors affecting the financial and economic viability or efficiency of reclamation or recycling schemes are also outlined on Fig. 2.1, including the external, or social benefits often associated with such schemes.

Determining the economic or social desirability of a reclamation or recycling scheme involves four steps: evaluating its financial viability; evaluating the social and environmental costs and benefits using cost-benefit analysis techniques; incorporating the monetary values obtained for these social costs and benefits into the financial evaluation framework to give an assessment of the economic efficiency of the scheme; arguing separately the cases of those social or environmental impacts of the scheme which are not given monetary values.

Section 2.2.1 below explains in greater detail how the financial appraisal of a reclamation or recycling scheme may be carried out. The techniques described and arguments concerning the appropriateness of their application in different situations also apply to the economic efficiency evaluation. Section 2.2.2 describes what the social and environmental impact effects of a reclamation or recycling scheme might be; and Sections 2.3, 2.4 and 2.5 examine the environmental impacts in greater detail, including how they may be valued.

2.2.1 The financial appraisal of reclamation and recycling projects

Proposed reclamation and recycling projects, as with other capital investment projects may be financially appraised using a variety of techniques (Lumby, 1981; Merrett & Sykes, 1963; and UNIDO, 1978). These techniques may be usefully divided into non-discounting and discounting methods, but both approaches aim to analyse the cash flows generated over the lifetime of the projects. The main non-discounting techniques are based on payback methods and return on capital. Discounting methods are based on the discounted cash flow approach, the major ones being Net Present Value and Internal Rate of Return. Clearly, the appraisal method selected will depend on the investment criteria, but the first stage in any assessment will involve the accurate determination of the project cash inflows and outflows.

Non-discounting methods: The payback method of financial or investment appraisal is a method of assessing how quickly the incremental benefits that accrue from the project pay back the initial capital invested. Hence a single project proposal may be accepted if the payback period is smaller than or equal to an acceptable time period, alternatively in a competing situation the project with the fastest payback period would normally be selected. The second non-discounting method considered here is return on capital employed and is calculated as the ratio of the accounting profit generated by the project to the required capital outlay including working capital. Projects with a return on capital above a specific minimum would be selected as would projects with the highest return in a competing situation. Both methods have advantages and disadvantages but overall they are considered useful

tools in that they are quick and simple to compute but suitable mainly for the analysis of small short-lived projects.

Discounting methods: For larger scale projects operating over a long period it is common to use techniques of evaluation which take account of the "time value of money" (Arnold and Hope, 1983). In these cases it is argued that it is not sufficient to evaluate competing or individual projects by comparing returns on capital invested, unless the timing of the returns are considered. Discounted cash flow techniques are employed to take account of the time value of money. These techniques include the net present value and internal rate of return methods (UNIDO, 1978). The first step in evaluating projects is to establish the relevant costs and returns, in the form of cash flows, over the investment life. Clearly the accuracy of the evaluation depends critically on the accurate determination of the cash flows.

The Net Present Value (NPV) of the project is defined as the value obtained by discounting separately for each year, the difference of all cash outflows and inflows accruing throughout the life of the project at a fixed, pre-determined interest rate. The discount rate should be equal either to the actual rate of interest on long term loans in the capital market, or to the interest rate paid by the borrower. If the NPV is positive, the profitability of the investment is above the cut-off discount rate, if zero, profitability is equal to the cut-off rate. Both of these are acceptable and the project in a competing situation with the highest NPV should be selected. If the NPV is negative, the profitability is below the cut-off rate and the project should be rejected. An alternative approach is to compute

the Internal Rate of Return for the project(s) under evaluation. The (IRR) is the discount rate at which the present value of cash inflow is equal to the present value of cash outflows. It is calculated by trial and error by using an estimated discount rate to discount the net cash flow to the present value. Calculations are continued until the net present value of the project is zero and this discount rate is termed the IRR and is the rate at which the present value of the receipts is equal to the present value of the initial investment. If the IRR is greater than the cost of capital then the project will be profitable. The project with the highest IRR should be selected.

In the preceding brief reviews of appraisal techniques, the importance of accurately forecasting the projects costs and revenues has been emphasised. Clearly, a thorough analysis of the projected financial performance of the project is a prerequisite in any calculation. Financial data required in estimating cash flows will include capital and working capital requirements, total production costs including factory costs, administrative overheads, sales and distribution costs, financial costs and, where appropriate, depreciation costs. Projected sales revenue will be a function of sales volume and selling price.

Clearly, much of the financial data required in an appraisal exercise cannot be forecast with any accuracy, this is especially true of sales revenue forecasts. This uncertainty is taken into consideration in the appraisal calculations by the use of techniques based on sensitivity analysis, statistical probability, risk adjusted discount rate, and the use of properties of a normal distribution. In particular, sensitivity analysis is a particularly useful technique for showing how the profitability of a project alters with differing parameter estimates.

2.2.2 Social costs and benefits of reclamation and recycling schemes

The main social and environmental benefits attributed to reclamation and recycling activities include:

(i) savings in collection and/or disposal costs, dependent on the waste management practise involved;

(ii) reduction in environmental impact by the use of reclaimed materials as raw materials inputs as compared to the use of virgin raw materials, including:

reductions in the amounts of virgin materials needed to be extracted and processed;

reduction in most cases, of overall pollution impact;

reduction in overall energy use;

(iii) a favourable balance of payments impact through the reclamation and recycling of domestic secondary materials;

(iv) employment creation benefits.

In considering the social desirability of a reclamation or recycling option, the activity in question should be considered jointly with any related disposal and the raw material extraction and processing activities. The disposal of waste materials to the environment (air, water and land) imposes costs on society, including various

financial costs (for labour, equipment and treatment plant) plus a range of external costs of environmental pollution and damage; as does raw material extraction and processing. Equally, reclamation and recycling and re-use are not costless activities and themselves involve collection, sorting, baling and processing costs and, in certain circumstances, pollution costs. All these social costs and benefits must be weighed together to give the relative costs and benefits of a reclamation and recycling option.

Depending on the type of scheme and the agency concerned with implementing it, the different social costs and benefits associated with a recycling option will have different effects and importance. A Local Authority may give higher priority to savings in waste disposal costs than it is willing to give to a reduction in energy use for example, as the former will directly affect its budget and the latter may be seen as of national concern. Alternatively private companies may not wish to consider either, although government may desire that they do so and impose fiscal or regulatory measures to ensure that they do. In this way government policy can provide a link between social and financial costs and benefits.

2.3 RESOURCE CONSERVATION

Recycling has the direct effect of reducing demand for a raw material where the waste product is used as a substitute for that raw material, and the more times a material is recycled the more this substitution effect is increased. However, the overall impact of recycling in reducing resource demands will depend on past and future levels of

resource consumption. Assuming that there is some growth in the consumption of a resource known to be reaching the limits of its reserves, Thomas (1979) shows how even maximum reclamation of all available waste material would only serve to postpone problems of that material's shortage for a limited period. Complete reclamation (ie 100%) is unobtainable. Some of the material used will be too widely dispersed to reclaim, such as lead in petrol; some changed or destroyed in use such as cigarette papers; and some in use indefinitely such as certain books, or steel in bridges.

Priorities in resource conservation have not been generally established, and neither are comparisons of the scarcity and the environmental costs of obtaining various resources, on which they might be based, readily available. Such comparisons should take account of a wide range of factors such as resources scarcity, energy costs, amenity loss, pollution and the generation of wastes, as well as political factors such as the distribution of, and access to, reserves. The economic framework discussed in Section 2.2 can be used to assess the social desirability of conserving particular resources, and hence to establish priorities in resource conservation. Some aspects of scarcity and environmental impact can be measured, such as costs of waste disposal and some pollution costs; although there is no consensus on how they are valued, as social costs and benefits, and hence evaluated by the economic efficiency criterion. Others such as amenity loss and some political factors may prove difficult or impossible to quantify in this way, and will hence need to be presented alongside the economic assessment as separately argued cases.

Environmental Resources Ltd (ERL) (1975) use this format in their assessment for the EEC of the relative significance of various social and environmental costs and benefits of reclaiming and recycling a number of materials. Table 2.1 shows their estimates of the potential value in the EEC of import savings and the scarcity values of seven important raw materials.

Table 2.1 SIGNIFICANCE OF SCARCE-RESOURCE AND IMPORT SAVINGS FROM RECLAMATION

Material	Import saving	Scarcity value
Ferrous materials	High	High
Non-ferrous metals	High (except aluminium)	Fairly High
Glass	Low	Low
Plastics	High	High
Rubber	High	Moderate
Textiles	Fairly High	Low
Chemicals	High	Moderate
Lubricating oil	High	High
Mining waste	Low	Low
Agricultural and food wastes	Low	Low
Combustible wastes used for energy	High	High

Source: Environmental Resources Ltd. (1976)

Most attention has been focussed on metals and fossil fuels in discussion of scarce resource savings, but scarcity is not the only factor to consider. The environmental degradation and loss of amenity associated with extracting or harvesting raw materials is also important. Generally in the case of non-renewable resources these effects increase as the resources themselves become less abundant and as poorer quality ore bodies are exploited with a higher percentage of overburden and hence wastes.

An important group of waste materials is that arising from mining and quarrying operations and which was estimated by Gutt et al. (1974) to amount to over 110 million tonnes annually in the UK. Most of these wastes are relatively innocuous, however their sheer bulk often creates considerable problems of disposal. In 1977 these wastes already covered a total of between 14,000 and 19,000 hectares of land. Recycling activities generally could contribute to reducing the environmental impact of mining and quarrying and reduce this dereliction in two ways; first by reducing the quantity of waste dumped, and second by reducing the need for raw materials to be mined and quarried.

Glass is a product whose raw materials (sand, limestone and soda ash) are abundant and indigenous but which cause problems of environmental degradation when they are quarried. Some of the best quality British sands come from the Lower Greensand formation in the King's Lynn and Redhill areas, far removed from the main glass manufacturing centres in Lancashire and Yorkshire. Expansion of quarrying for these high-grade sands, Friends of the Earth (FOE) (1977) argue will involve environmentally sensitive areas where amenity and ecological losses will be considerable. FOE (1977) also argued that increased recycling of waste glass, or the use of lower-grade sands which are suitable for coloured glass, could reduce significantly this adverse environmental impact.

Bate (1976) discussed the environmental impact problems caused by the extraction of limestone, again used in glass manufacture. Limestone is found in areas such as the Peak District and the Yorkshire Dales; areas with high amenity value, and consequently areas where the social

costs of noise, dust, heavy transport and pollution caused by quarrying are less likely to prove acceptable.

The use of renewable resources can also involve problems of limits to exploitation, and of adverse environmental impact. For example Thomas (1977a) discusses both the economic constraints on the expansion of wood-pulping operations and the ecological consequences of expanding into large areas of presently unexploited forest. The availability of land for forest expansion is another constraint, as land itself may be considered a scarce resource in many areas. An increase in the recycling of waste paper can by reducing the demand for virgin wood-pulp lessen the pressure on forest resources. This conclusion was reached by the Organisation for Economic Cooperation and Development (OECD) (1979):

"All in all, the heavy harvesting rates now taking place would suggest that recycling can contribute something to forest preservation."

They did however add a note of caution, with the comment that forest conservation may not always be achieved through recycling, as re-afforestation may not occur:

"Trees may not therefore be 'saved' by recycling - they may simply not be planted."

To bring a natural, unmanaged forest under management often means to replace the natural forest vegetation by forest monocultures of plantations of economically profitable trees. This can be enormously

disruptive to the ecological balance of the forested area. Loss of habitat and changing conditions may destroy many native species adapted to live in a particular forest environment, as well as the economically useless trees. The spread of easily managed forest monoculture also leads to concern about the effects such management systems have on both soil and water resources. Large-scale forest removal can result in soil erosion, changes in soil quality and nutrient levels, and there may also be long-term climatic effects. (See Thomas (1977), Searle (1975) and Peliset (1975)). Predicting and quantifying all these factors presents considerable problems. Effects on soil quality could for example be costed in relation to the future agricultural/silvicultural productivity of the soil; however effects on habitat, flora and fauna, and possible long-term climatic changes are much more difficult to value.

2.4 ENERGY

A strong argument in favour of increased recycling of materials is that it can greatly reduce the energy costs associated with a given level of materials consumption. Obviously any direct monetary benefits due to the low energy use of any particular recycling option would be incorporated in the financial evaluation of its private costs and benefits. However there is a wider social cost benefit impact of reducing energy demand through increasing recycling activities concerned with the socio-political aspects of energy supply and use, such as future availability, political constraints on supply and the environmental impact of energy generation. This leads to the question

of whether the market price accurately reflects government/societies concern for these factors, and whether it can adequately reflect the comparative energy use between any recycling option and the use of virgin raw materials to produce the same goods. That comparative energy use between recycling and virgin raw materials use is frequently cited as a social or environmental benefit of recycling activities (see for example O'Riordan and Turner (1981), OECD (1983), USEPA (1979), OECD (1979), ERL (1975)) implies common concern that the market-price does not adequately reflect these factors. Energy use can be accounted for either in units of energy used or in money value (by calculating a shadow price based on its sociopolitical evaluation). The latter however is not commonly used. In the following discussion comparative energy use as a measure of environmental impact will be considered in terms of units of energy required by different options, such that comparative energy consumption is presented as a separately argued impact in the overall analysis.

Comparison between the energy requirements for a number of metals produced from secondary materials and from their ores shows that in the former case energy needs are invariably smaller, often dramatically so. For example, Chapman (1974) estimated that the production of one tonne of copper from US open-pit mined ore required about 10 times the 9,000 MJ required for production from municipal scrap; aluminium, more dramatically, required 327,600 MJ per tonne when produced from bauxite, but only 10,800 MJ per tonne from scrap - one thirtieth of the energy demand. This energy gap was likely to increase as new supplies are extracted from even lower-grade ores or resource deposits.

The energy savings that can be achieved through recycling other materials may not seem so dramatic in comparison but are often nonetheless significant. It is though often difficult to obtain reliable estimates of the relative energy use in recycling and in virgin raw materials production. Widely varying figures are quoted in different studies, usually a result of different factors being used in the analysis. One example of this can be found with reference to recycling in the production of steel. Davis (1974) estimated that steel produced from scrap required about 30% of the energy of that produced by iron ore, a saving of around 14,400 MJ per tonne of scrap recycled. Wilson (1979) in calculating the energy savings per tonne of recycling ferrous scrap reclaimed from domestic refuse compared with manufacture from virgin raw materials, used a figure 25,000 MJ per tonne of scrap recycled.

Metals are not the only materials to benefit from reduced energy consumption when produced from waste materials. Grace and Turner (1976) quote figures from USEPA (1973) taken from an environmental impact analysis of energy savings achieved by recycling waste paper compared to production from virgin pulp. Two comparisons were considered, and the results are shown in Table 2.2; the production of a low-grade pulp, which showed a 12,000 MJ per tonne or 70% saving in energy using 100% recycled fibre, and the production of a high-grade pulp, showing a 14,000 MJ per tonne or 60% saving in energy again using 100% recycled fibre.

Love (1979) also calculated the energy savings in three different types of paper mill when recycled fibre replaced virgin fibre as a raw

Table 2.2 ENVIRONMENTAL IMPACT COMPARISON: PRODUCTION OF VIRGIN PULP AND RECYCLED FIBRE PULP

Type of impact	To produce 1,000 tonnes of low-grade pulp			To produce 1,000 tonnes of high-grade pulp		
	Unbleached virgin pulp	100% repulped paper waste	Effect of using repulped paper waste (%)	Bleached virgin pulp	De-inked repulped paper waste	Effect of using de-inked pulp (%)
Virgin materials use	1,000 tonnes		- 100	1,100 tonnes		- 100
Water use	100 x 10 ⁶ litres	42 x 10 ⁶ litres	- 61	195 x 10 ⁶ litres	166 x 10 ⁶ litres	- 15
Energy use	17 x 10 ¹² joules	5 x 10 ¹² joules	- 70	23 x 10 ¹² joules	9 x 10 ¹² joules	- 60
Air pollutants	42 tonnes	11 tonnes	- 73	49 tonnes	20 tonnes	- 60
Waterborne wastes - BOD*	15 tonnes	9 tonnes	- 44	23 tonnes	20 tonnes	- 13
Waterborne wastes - SS**	8 tonnes	6 tonnes	- 25	24 tonnes	77 tonnes	+ 222
Process solid wastes	68 tonnes	42 tonnes	- 39	112 tonnes	224 tonnes	+ 100

* Biochemical oxygen demand

** Suspended solids

Source: Grace and Turner (1976)

material, taking into account the energy cost of reclamation. The results (shown in Table 2.3) range from 7,300 to 30,600 MJ/tonne of paper produced; the wide variation being due to the widely differing production requirements of the different products involved. Two other studies, by Hunt and Franklin (1973) and Gordian Associates (1976) both quoted in OECD (1979) again show total net energy savings from recycling waste paper, (see Table 2.4).

Table 2.3 ENERGY SAVINGS IN PAPER PRODUCTION WITH RECLAIMED FIBRE

Type of paper	Energy savings from 100% recycling compared to production from virgin pulp MJ/tonne of paper produced)	Energy savings (MJ/tonne waste paper recycled)
Newsprint	11,800	10,600
Tissue and sanitary paper	30,600	27,600
Corrugated board	7,300	7,000

Source: Love (1978)

There is no consensus view on how the energy consumption of a particular material or process should be calculated. Studies vary from considering only the energy used in the manufacturing process from raw material delivered to finished product leaving the industrial premises; to attempts to include all energy used in producing a good or service from the initial extraction of all the raw materials involved through processing and manufacturing, and including all waste disposal, reclamation and recycling energy costs. Most studies of the environmental impact of recycling processes fall somewhere between

these, for practical, if not ideological reasons, and recognising that different types of comparative studies will be valid for different situations depending on the context and objectives of the studies concerned. What is important though is that any study of comparative energy use of producing a good from recycled and virgin raw materials in internally consistent.

Table 2.4 ENERGY SAVINGS FROM RECYCLING PAPER

Product	Total net energy savings from recycling (MJ/tonne)	
	Hunt & Franklin (1973)	Gordian Assoc (1976)
Newsprint	+ 118,000	+ 175,000
Printing and Fine Tissue	+ 169,000	+ 193,000
Industrial Containerboard	+ 116,000	+ 60,000
Folding Box/Other	+ 211,000	+ 220,000

Source: OECD (1979)

OECD (1979) also discusses the problem encountered in energy analysis of distinguishing between industry self-generated energy, and fuel purchased. Different analyses will account for these energy sources differently, hence producing widely varying results. The report concluded that there was no doubt of an overall energy saving through recycling paper, and that recycling waste paper competes more than favourably in energy terms with its use as a fuel using heat recovery methods. In considering purchased energy alone however the savings

were reduced. Although they found a clear energy advantage in using waste paper for newsprint, for other products a less favourable picture emerged.

An area in which energy cost has attracted a great deal of attention is that of glass containers. The Industry Committee on Packaging and the Environment (INCPEN) (undated) claimed a 1.5% saving in furnace energy could be achieved by a 10% increase in recycling waste glass. More significant energy savings have been claimed for the reuse of glass containers; in the order of 25-40% of the energy required for a one-trip container system (Thomas, 1979). Considerable controversy though has emerged over the extent of the environmental benefits of returnable or reusable glass containers, involving numerous comparative studies, especially in the USA (see Thomas (1979) and OECD (1978)). However, the debate is too complex to attempt to summarise here.

Another area where energy savings could be achieved through reclamation and recycling activities is in waste management practice. Wilson (1979) calculated the energy cost of various waste management methods, and found that landfill (treated and untreated) and non-recuperative incineration made net energy losses per tonne of waste treated, and that reclamation, production of refuse derived fuel, and incineration with steam raising made net energy gains.

Table 2.5 shows the energy balance, based on Wilson's figures, for local authority waste management practice in 1978/9. This energy deficit would be turned into an overall energy saving if greater emphasis were placed on reclamation, and on energy recuperation from domestic refuse.

Table 2.5 ENERGY COST OF LOCAL AUTHORITY WASTE MANAGEMENT PRACTICE

Method of Waste Management	Current Practice 1978/79		
	Amount Disposed of (m tonnes)	Energy Cost MJ/tonne	Total Energy Cost 10^6 MJ
Landfill (untreated)	18.2	190	3458
Landfill (shredded or pulverised)	0.7	555	388.5
Landfill (by contractor/transfer)	4.0	460	1840
Incineration (non-recuperative)	2.6	890	2314
Reclamation	Amount recovered		
Fe metal	0.05	- 25000	- 1250
Waste paper	0.30	- 19000	- 5700
TOTAL	25.5		1050.5×10^6 MJ

2.5 POLLUTION

It is most often the case that, when the complete process from the acquisition of the raw materials to final disposal are taken into consideration, the recycling of waste materials is associated with lower levels of polluting discharges than the production from virgin raw materials that it replaces. However, there is still cause for concern about the actual polluting emissions of particular recycling

processes. For example Table 2.2 shows high levels of water-borne wastes, both in terms of suspended solids and in biological oxygen demand for the production of high-grade de-inked recycled pulp. This environmental impact comparison also highlights the relative increased environmental impact associated with the production of higher quality pulps (recycled or not) and the reduced environmental benefits achieved through recycling in the case of high-grade pulp production.

Love (1976) reports lower levels of air and water pollutants for production from recycled fibres in the newsprint, tissue and sanitary paper and corrugated board mills studied. This reduction was achieved even in the case of the de-inking operation in the tissue and sanitary paper production. Love described the operations as 'exemplary' and concluded that his findings should be interpreted as indicating that de-inking processes need not result in increased water pollution, although he recognised that in many cases they do.

De-inking waste paper, and the production of high grade recycled pulps though can generate pollution problems. Another approach to this, is to consider whether lower product specifications could win consumer acceptance. OECD (1979) put this point very clearly in this quote:

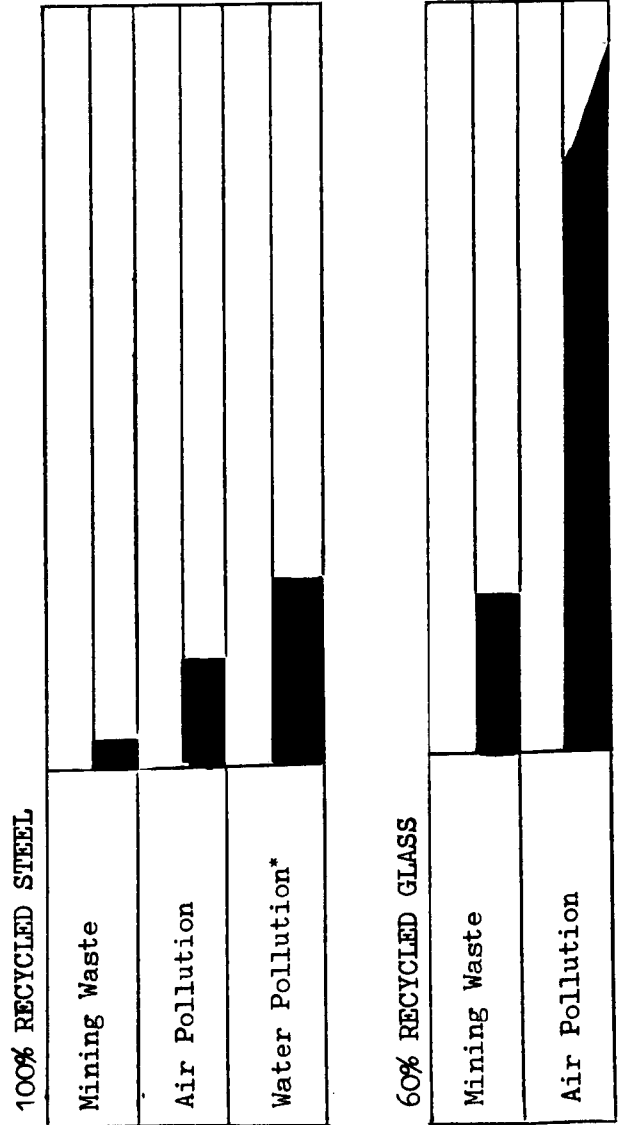
"... if paper brightness is reduced, a less 'aesthetic' product is obtained but it would be one that permits an increased use of secondary fibre or necessitates less de-inking. As soon as brightness specification is changed, the environmental effects become less ambiguous. In tissue manufacture a reduction in brightness from

80 GEB to 20 GEB (the latter is the brightness of unbleached Kraft) would, according to the Bower studies, reduce SO^2 (air pollution) by 50%; dissolves solids by 85% and biological oxygen demand (BOD) by 80%. But suspended inorganic solids would still be increased. European experts suggest that the hypothesised change from 80 to 20 GEB in brightness is non-feasible but that 80 down to 60 would be commercially realistic. In this case, of course, the environmental benefits remain positive but nowhere near as significant as reported in the previous example."

Substantially lower pollutant discharge levels have been found to be associated with the processing of other reclaimed materials, in comparison to production from virgin raw materials. ERL (1975) quotes figures for glass and steel production obtained from the US Environmental Protection Agency, and these are shown in Fig. 2.2. Recycling steel shows significantly reduced air and water pollution impacts compared to its production from virgin raw materials; whereas for glass production the polluting emissions from recycling are less but not dramatically so.

Considering the range and diversity of substances and effects grouped together as polluting emissions, it is difficult to generalise about their environmental impacts. Pollution can be, for example, excessive noise, or certain suspended solids in water, or substances causing an increased biological oxygen demand in water or certain particulate or gaseous emissions in air. All these effects can be quantified

Fig 2.2 ENVIRONMENTAL IMPACTS OF RECYCLING GLASS AND STEEL



* Biological oxygen demand and suspended solids.

- Environmental impact when virgin raw materials used.
- Environmental impact when recycled material used.

Source: Environmental Resources Ltd (1975)

individually using a variety of measurements, such as decibel units for noise, and actual quantity by weight of specific emissions, for example tonnes of sulphur dioxide. Environmental Impact Assessment requires some overall comparative evaluation of these different polluting emissions.

This can be done in the format shown in Table 2.2, taken from an EIA study undertaken for the US Environmental Protection Agency (USEPA (1973)), where different polluting emissions are separately quantified and listed, with no attempt to compare for example the social value of 1 tonne of air pollutants and 1 tonne of waterborne wastes. However, much work has been done to attempt such a comparison of social value, and include different polluting impacts in social cost-benefit analysis. Pearce and Turner discuss, in Pearce (1978), several methods of evaluating the social costs of noise, air and water pollution. These include using property price variations to the social cost of both noise and air pollution; corrosion damage costs for both air and water pollution; medical costs, and the cost of lost life and impairment due to disease where health hazards are caused by water pollution in particular; and interview techniques and other estimates of the public's willingness to pay for recreational damage due to water pollution. No consensus has been reached over an appropriate approach to pricing these social costs, and argument continues as, as O'Riordan (1981) expresses it,

"Economists continue to ponder methodologies to price
the unpriceable."

CHAPTER 3

DOMESTIC REFUSE : ITS DISPOSAL, RECLAMATION AND RECYCLING

It was estimated by the Departments of the Environment and Industry (DOE/DOI, 1974) that each year in Britain over 170 million tonnes of waste materials are disposed of. Nearly 150 million tonnes of this total are industrial wastes comprising of 110 million tonnes of mining and quarrying waste, 12 million tonnes from power stations, 3 million tonnes from building work, and about 23 million tonnes of general industrial waste. The remaining wastes, just over 25 million tonnes in England in 1978-9 according to the Society of County Treasurers, County Surveyors Society and Chartered Institute of Public Finance and Accountancy (SCT, CSS and CIPFA) (1980), are household and commercial wastes. It is this last group that this research project is primarily concerned with.

Industrial wastes, apart from their larger quantities, are a much more diverse group of materials ranging from the inert and innocuous to those which present some hazard in disposal due to the toxic, corrosive, combustible, caustic or irritant nature of the material. Thomas (1977b), concluded that insufficient, detailed data was available concerning the quantities, composition and potential hazards of industrial wastes. This is not only cause for concern over safe disposal methods, but makes it extremely difficult to generalise about the disposal, reclamation or recycling of all the materials included in the description industrial wastes. Some industrial wastes being available as homogenous, concentrated supplies of material will be considered as high-grade wastes, easily reclaimed and recycled. Much

of this type of material in fact will not even be recorded as an industrial waste material, as it will either be reclaimed within the plant or has become an industrial by-product, sold for further processing or recycling. The 150 million tonnes of industrial wastes referred to above does not include those wastes already reclaimed and recycled, but refers to those disposed of every year.

This Chapter looks, in Section 3.1, at the quantities and composition of domestic refuse generated in Britain, and at how they are currently managed, or disposed of. Only around 1% of domestic waste is reclaimed and recycled, and Section 3.2 describes current recycling practises relevant to those reclaimed materials.

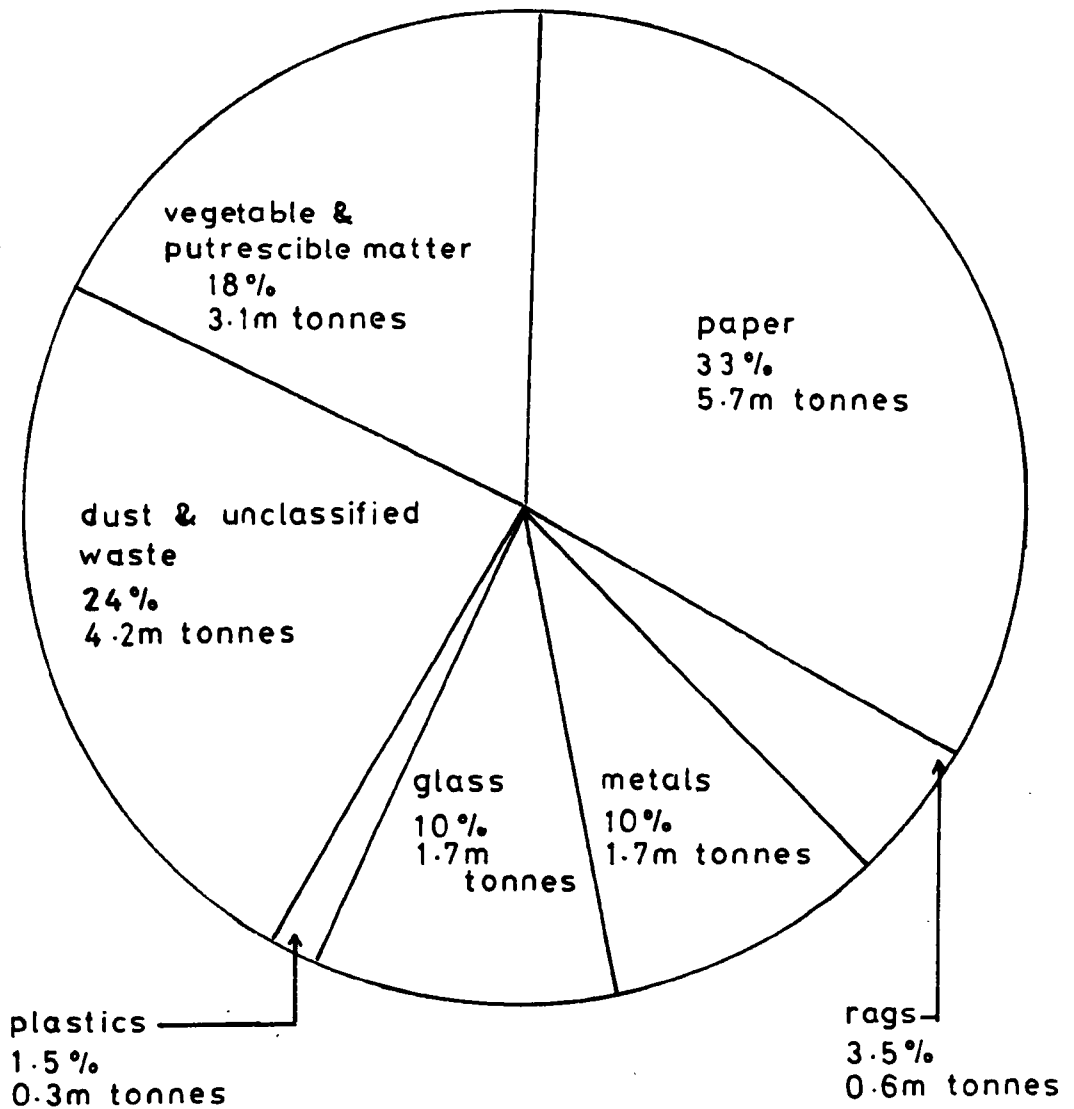
3.1 CURRENT WASTE MANAGEMENT PRACTICE FOR DOMESTIC REFUSE

3.1.1 Composition of domestic refuse

The composition of domestic refuse in Britain varies considerably from area to area, and periodically attempts are made to define an average composition for the country as a whole, usually taken from detailed local analyses. The most recent published analysis available seemed to be that quoted by the Waste Management Advisory Council (WMAC) (1976) and this percentage composition was used to calculate the likely quantities of each constituent waste material disposed of in domestic refuse in England in 1978/9. The results are shown in Fig. 3.1. It is likely that the composition of domestic refuse has however changed since 1973, with in particular, the proportion of plastics wastes having most probably increased from the 1.5% shown in Fig. 3.1.

Fig 3.1 AVERAGE COMPOSITION OF DOMESTIC REFUSE IN ENGLAND

Showing: % composition by weight (1973)
 Amount by weight (1978/9)
 (Total amount by weight = 17.3m tonnes)



Source: WMAC (1976) and SCT,CSS and CIPFA (1980)

By far the largest single constituent of refuse is paper accounting for about 33% by weight. Just over half of this is packaging materials the rest being mainly newspapers and magazines, (Thomas, 1979). In addition to paper packaging waste must be added glass containers and 'tin' cans, which make up the bulk of the metals and glass in domestic refuse, and plastics packaging. In total, packaging materials were estimated by the DOE (1971) to account for nearly 40% of domestic refuse at that time.

DOE (1971) highlighted some important trends in the changing composition of domestic refuse over the period 1935-1968. A reduction in total weight of refuse per household seen in that period was explained by the reduced proportion of dust and cinder resulting from changing patterns of home heating. They also revealed a 44% increase in the volume of domestic refuse over the same period.

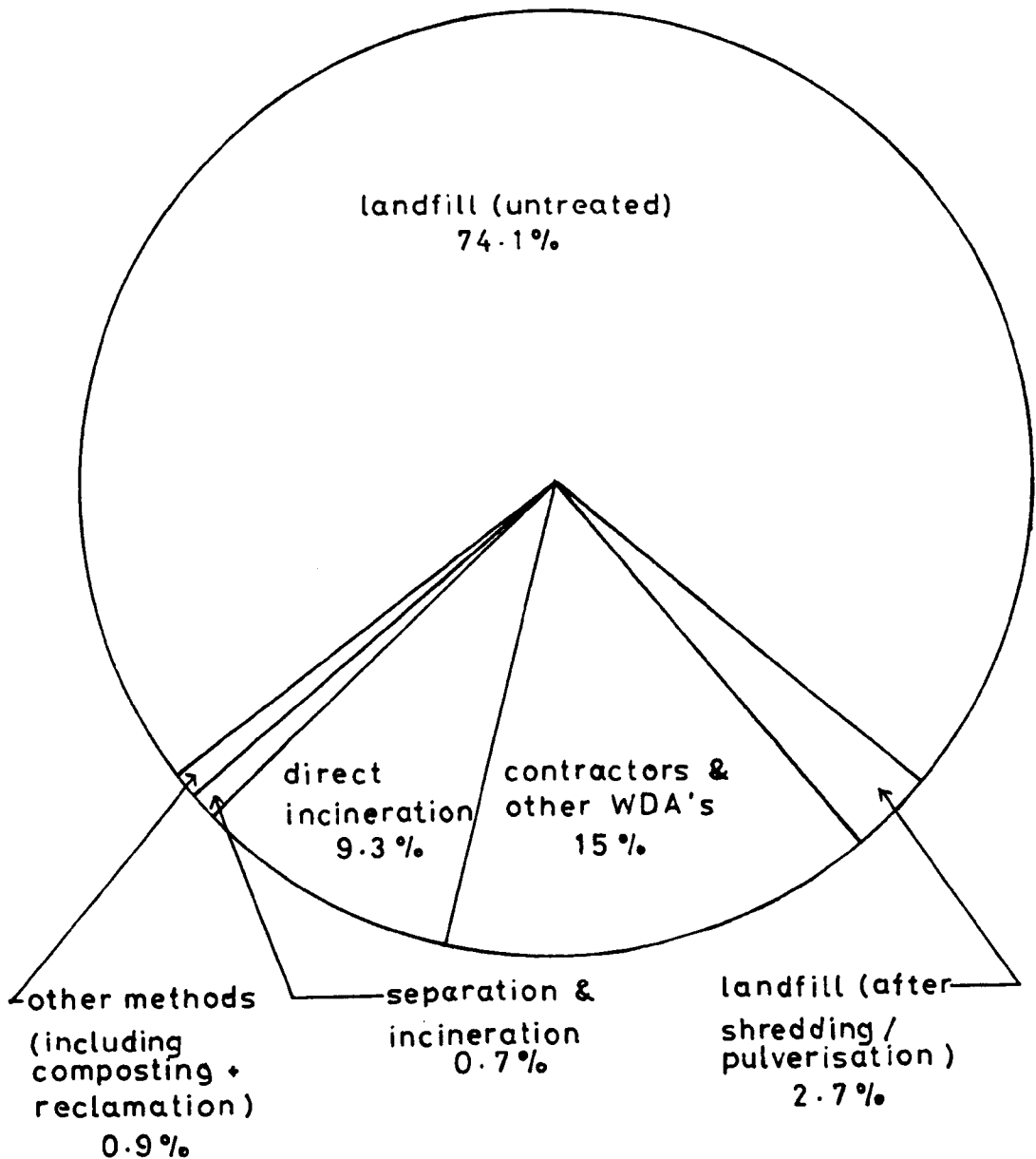
3.1.2 Waste management methods

Domestic waste management (or disposal as it is more commonly referred to) is a function of the County councils in England, of the District councils in Wales and of the District and Island councils in Scotland. These are all now known as Waste Disposal Authorities (WDAs). Refuse collection is still the responsibility of the District councils in England, Wales and Scotland.

The waste management methods used by the WDAs in England in 1978/9 are shown in Fig. 3.2 Landfill is by far the most common method, used

Fig 3.2 REFUSE DISPOSAL METHODS 1978/9

Method used by WDA's by % of refuse disposed of:



Source: SCT, CSS and CIPFA (1980)

for 89% of domestic refuse. Incineration is the only other significant method used.

Both these methods are used predominantly to facilitate the disposal of refuse. Waste utilisation or reclamation is given a very low priority in current solid waste management practice. Some landfill is used as a means of reclaiming derelict land, and a small amount of energy recovery is practised with incineration. This apart, the only refuse utilisation carried out is confined to the less than 1% 'other' methods, and some reclamation achieved by collection authorities.

A small amount of reclamation is carried out by collection authorities and involves predominantly the separate collection of waste paper and more recently (due to the introduction of 'Bottle Banks') the separate collection of waste glass. Both paper and metals (non-ferrous and ferrous, although largely the latter) are reclaimed by WDAs, using hand and mechanical separation. The total quantity of materials reclaimed by these methods, estimated at approximately 250,000 tonnes in 1978/9 by SCT, CSS and CIPFA (1980) and BPBIF (1980), amounts to about 1% of the total amount of domestic and commercial waste collected and disposed of. The reclamation methods used by local authorities are described in greater detail in Chapter 4.

Other waste utilisation methods currently used by WDAs include composting and the production of Refuse Derived Fuel (RDF). These are discussed further, together with the other available options for waste utilisation, in Chapter 4, in relation to how reclamation from domestic refuse might be increased.

3.2 CURRENT RECYCLING PRACTICE IN BRITAIN

Significant levels of recycling activities occur in Britain in an extremely wide range of industries. Fig. 3.3 shows the recycling rates for a number of materials all of which are found, although in some cases in small quantities, in domestic wastes. 'Recycling rate' refers to the amount of reclaimed material used as a percentage of the total amount of raw materials used in the manufacture of a particular product; this is also called the *utilisation rate* (OECD, 1979). Another ratio often used to quantify reclamation activity is the *recovery rate* which is the amount of reclaimed material used in the manufacture of a particular product as a percentage of the total consumption of that product.

These recycling rates refer to the total amount of waste used in each particular materials industry, including that which arises and is used within the same plant, manufacturing wastes, and post-consumer waste (discarded or used materials).

Post-consumer waste usually only accounts for a small proportion of the total wastes used. Chapman (1974) found that for copper, the recycling rate due solely to post-consumer scrap was only 13%, compared to a total recycling rate of 37%, the Glass Manufacturers Federation (GMF, undated) estimated that in 1973 of the total 22% recycling rate, only 3% was accounted for by post-consumer waste; and the DOE (1974) concluded that for steel production the recycling rate for post-consumer scrap was only 10% of the 53% total recycling rate.

Fig. 3.3 RECYCLING RATES IN BRITAIN

Material	Recycling rate: reclaimed material as a percentage of total raw materials used
Iron and Steel	53.0
Copper	37.0*
Aluminium	26.0*
Zinc	21.0*
Lead	62.0*
Glass (containers)	22.0
Paper	44.0
Wool	10.5
Cotton and man-made fibres	14.5

* Recovery rate: reclaimed material as a percentage of total consumption

Source: Thomas (1979)

Of these post-consumer wastes reclaimed and recycled, the majority arise from industrial or commercial sources. Domestic waste materials currently play a fairly small role in recycling in Britain due to the small quantities reclaimed. Paper and ferrous metals, and more recently glass, are the materials most extensively reclaimed by local authorities; added to these are quantities of paper, textiles, non-ferrous metals, and some lubricating oils, waste plastics and waste glass collected by scrap merchants, individuals and charity/voluntary groups. This section considers briefly how these domestic waste materials are currently recycled, and some opportunities for their increased recycling.

3.2.1 Metals

Most of the processing of metal scrap for recycling is involved in reclamation and separation from other contaminants, which can involve complex processes and equipment. Recycling in many cases will only involve adding the scrap metal to the smelter and remelting.

Ferrous metals: Post-consumer scrap used in the steel industry includes items such as industrial plant, 'old' ships and consumer appliances.

There is considered to be considerable scope for additional reclamation of post-consumer scrap ferrous metal, with the biggest potential being in domestic refuse and scrapped cars. Nearly 2 million tonnes of ferrous metal mostly in the form of 'tin' cans is disposed of in domestic refuse annually, and Barnes (1974) calculated that scrapped

cars could yield an additional half million tonnes of ferrous metal if they were all reclaimed.

The upper limit to the amount of ferrous scrap that can be recycled in steel production, as distinct from the amount that can be reclaimed, must eventually be set by the types of production processes used, as different processes can accommodate different proportions of waste material. Electric-arc furnaces can take up to 100% scrap, whereas open-hearth furnaces can operate using between 25% and 75% scrap, and the oxygen process only takes 30%. The trend has been towards increasing use of electric-arc processes, which should make higher recycling levels possible.

A common problem associated with much post-consumer metals reclamation and recycling is illustrated extremely well by the example of the 'tin' can. The main proportion of this product is steel, covered by a very thin coating of tin and soldered together by a tin/lead alloy. It may also be contaminated with lacquers, organic wastes and with aluminium. All easy-open, ring-pull cans have aluminium tops. This metal mixture complicates recycling.

'Tin' cans can be recycled in two ways; by de-tinning and by melting. De-tinning involves the separation of tin and steel by electrolysis (decomposition by an electric current). It is very efficient recovering 99.98% pure tin, and de-tinned steel which is sold as scrap for further processing. Melting processes only allow the recovering of the steel base. Some of the tin content is burned off during the process but enough remains to make the ferrous material

unacceptable for use in steel production. Instead it is returned to iron foundries. De-tinned steel can be used directly in steel production, or in copper mining processes, for which it is exported to Africa. De-tinning would thus seem the preferable process, recovering maximum value from the can. Both processes are in use in Britain and the British Tin Box Manufacturers Federation (BTBMF) (1973) estimated that of the total production of tin-plate of 900,000 tonnes per annum in 1970 about 14% was recovered and de-tinned, and 17% recovered and melted down.

Unfortunately, de-tinning has been on the decline in recent years, at least for post-consumer waste. Virtually all the tin-plate currently de-tinned is manufacturers' waste, where there is an impressive record. What post-consumer waste is recovered from domestic refuse appears to be melted down, often because the cans have been incinerated and the tin already burnt off.

Non-ferrous metals: The high value of many non-ferrous metals has proved considerable incentive for their recycling, although in many cases reclamation is hampered, or made impossible, by a particular type of product used. For example, the use of copper in electric wires and cables, zinc in galvanising and lead in solder and collapsible tubes (eg toothpaste), make their reclamation from post-consumer wastes problematic. Most lead is used in batteries though, and here reclamation is very high. Aluminium is used widely in packaging materials, and little reclamation from this source has occurred todate, except for charity collections of aluminium foil and some recent attempts to encourage the public in a few experimental areas to reclaim aluminium cans.

3.2.2 Paper

Waste paper is used extensively in the British paper and board industry, and its recycling primarily involves repulping and cleaning operations prior to converting into paper products either directly or after mixing with virgin wood pulp. Paper mills which use post-consumer wastes are equipped with some specialist plant designed for processing recycled fibres. This will range from just repulping and simple cleaning equipment for mills producing lower grade products to more extensive cleaning and fibre upgrading equipment, including de-inking processes, if higher grade papers are produced.

Although reclaimed fibre accounts for nearly 58% of the raw material used in paper and board manufacture in Britain, statistics from the Central Statistical Office (CSO) (1982) show that it only represents 33% of the paper consumed, due to the high level of imports of finished papers and paper products. As Section 3.1 shows, only about 0.2 m. tonnes of almost 6 million tonnes of waste paper in domestic refuse is currently reclaimed, and it is commonly agreed that here lies the greatest potential for increasing reclamation.

The Paper and Board, Printing and Packaging Industries Research Association (PIRA) (1974a) considered the question of whether, given such a potential increase in waste paper reclamation the paper industry would be able to absorb the resultant reclaimed fibre. They concluded that maximising the use of waste with the then currently available technology would probably enable an increase in the recycling rate from 44% to 58%. This recycling rate has now been achieved, although

it could most probably now be increased further given additional technical developments, and some acceptance of lower quality papers.

Virtually all post-consumer waste paper currently reclaimed is consumed in producing packaging papers, which Massus (1974) estimated consumed some 90% of total waste paper used in the British paper industry. Any significant expansion in recycling must occur therefore in other product areas, such as printing and writing papers, tissues and newsprint. Thomas (1977a) considered that the potential for increased use of recycled fibre in these products was good, provided a necessary, accompanying reduction in quality standards was accepted.

3.2.3 Glass

Direct recycling of waste glass (or cullet) basically involves remelting in a glass furnace. In glass container manufacture, cullet is added to the furnace along with other raw materials. Glass manufacturers demand high quality standards in the cullet they purchase, with regard to impurities, which can cause damage in the furnace, and the composition or colour, as this affects blending in the furnace.

Only 3% of the raw material used in glass container manufacture was post-consumer waste glass in 1973. Of this, the Glass Manufacturers Federation (GMF) (1974) estimated, about 2% was due to breakage or rejection of containers, before use in bottling or filling plants; leaving an overall 1% (25,000 tonnes in 1973) as containers reclaimed

after use. This recycling rate has recently been improved though, as a result of increasing amounts of post-consumer waste reclaimed through the 'Bottle Bank' scheme (described more fully in Chapter 4). Current figures (GMF, 1982) show over 60,000 tonnes of post-consumer waste glass reclaimed.

3.2.4 Plastics

Thermoplastics account for the major share of plastics produced and can be softened and remoulded on heating. Thermosetting plastics are hardened during their production by extensive cross-linking of the polymer chains and cannot be remoulded. This limits their recycling potential to use as fillers, or as a potential source of energy.

Individual thermoplastics, provided they are fairly clean and free of contaminants, can be readily recycled, as can most process wastes, by feeding them back into the production process. Industrial process wastes present little problem and an increasing number of plastics companies are carrying out their own internal recycling. Those companies where internal reclamation is not economic are generally covered by external reprocessors, provided their waste arisings are fairly homogenous and uncontaminated. Reprocessing of such process wastes, whether internal or external, involves presorting and granulation, blending and colouring, extrusion and cooling, followed by final size reduction and packaging.

Bollard and Vogler (1981) estimated that in Britain between 40,000 and 50,000 tonnes per annum of process plastics waste is generated and recovered within the factory. Process waste generated, but not recycled, by the British plastics industry was estimated by Environmental Resources Ltd (ERL) (1975) to be 100,000 tonnes in 1973.

Post-consumer waste plastics accounts for much larger amounts. The conservative estimate of plastics in domestic refuse quoted in Section 3.1 shows some 300,000 tonnes annually. Bollard and Vogler (1981) give a higher figure of 750,000 tonnes per annum. Virtually none of this is recycled, mainly because of the considerable problems of collection and separation that it presents. Some post-consumer plastics wastes are recycled though, mainly from sources other than domestic, and estimated by Bollard and Vogler (1981) at 20,000 tonnes per annum.

Recycling post-consumer plastics wastes cause a number of problems not experienced with process wastes. Post-consumer wastes generally contain more than one polymer and these must either be separated or processed as mixed plastics. The latter can be used as an energy source or formed into a composite material. A number of processes have been developed to recycle mixed plastic waste and are described more fully in Chapter 5.

3.2.5 Textiles

Once an important recycling activity, textile reclamation and recycling has declined dramatically in recent years due to increasing use of

synthetic fibres, and because of competition from cheap imported textiles. Some textile reclaimers have survived mainly, according to Bollard and Vogler (1981) exporting rags to Italy.

'Jumble sales' and second-hand clothing is another, and probably more common outlet for recycling domestic waste textiles today.

3.2.6 Lubricating Oils

Waste lubricating oils can be recovered and recycled into useful products; most contaminated oils can be cleaned or re-refined to be used as a fuel. The DOE/DOI (1974) estimated that in 1973 Britain consumed over 1 million tonnes of lubricating oils, generating 600,000 of waste oil; between 66,000 and 80,000 tonnes of this was re-refined and a greater quantity usefully burned.

Domestic arisings of waste lubricating oil comes from private motorists carrying out oil changes. Collection points for this oil exist on many civic amenity sites and in garages. Much more could be done to publicise their existence and hence increase reclamation from this source. One survey carried out by Over (1979) found that 65% of motorists interviewed did not know where their nearest collection point was.

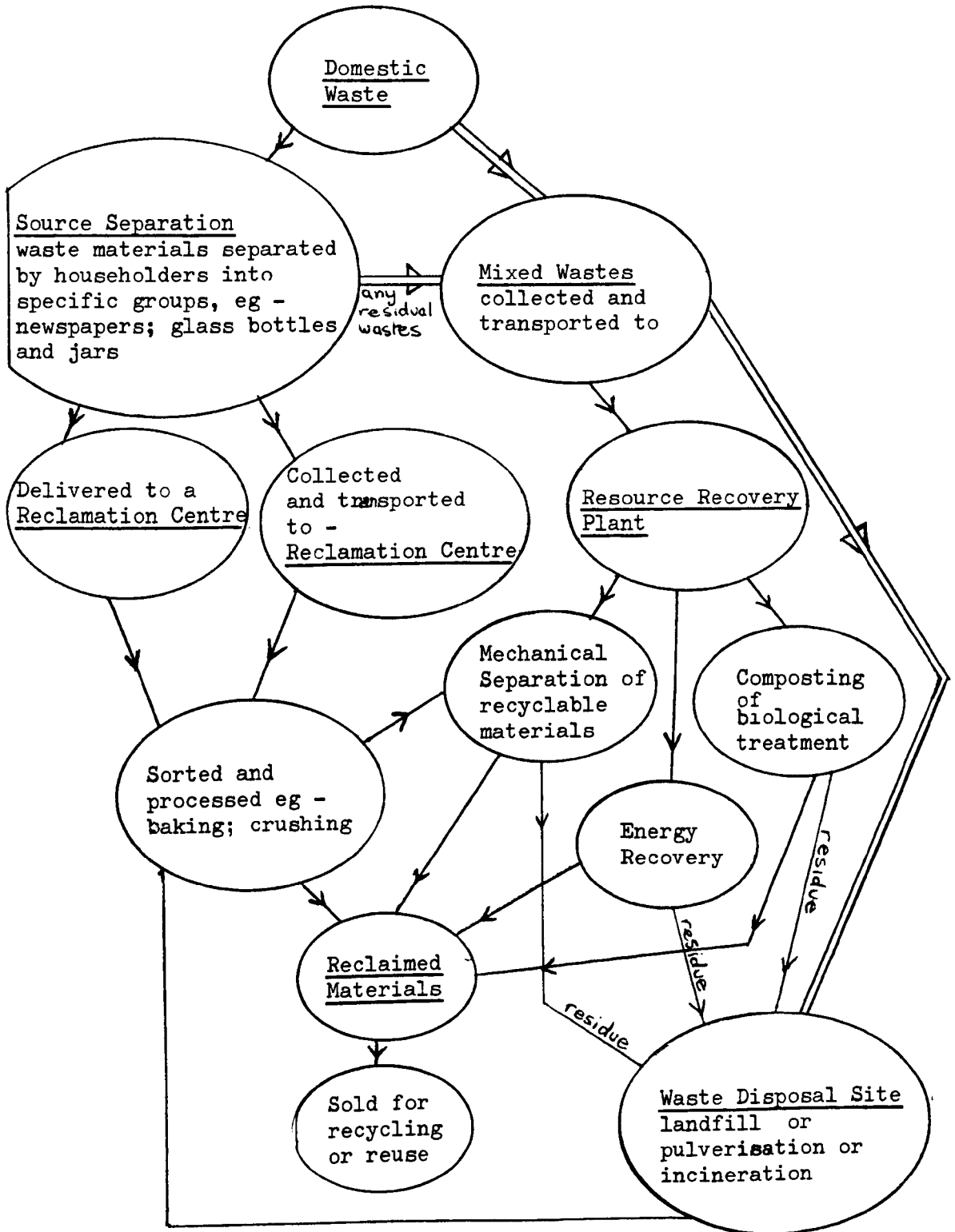
CHAPTER 4'COMMUNITY' SCALE RECLAMATION

The value of increasing the amount of domestic waste reclaimed and recycled was discussed in Chapter 2, leaving the question of how an increase in reclamation might be achieved. This chapter explores some of the waste management options available which would enable an increased level of reclamation, and assesses their appropriateness to the Community Technology approach. The current state of reclamation in Britain is considered and a number of source separation schemes are examined in detail. The following section describes the experience of community source separation in the USA, with reference to particular schemes drawn mainly from personal experience gained during a research tour in 1980. The last section attempts to develop criteria for a model of community scale experience and research on participation rates, yields of materials and organisational aspects of source separation reclamation schemes.

4.1 RESOURCE RECOVERY OR SOURCE SEPARATION - WHICH ALTERNATIVE TO DISPOSAL?

Considerable attention has been focussed in recent years on developing waste utilisation techniques and systems, producing a wide variety of waste management options based on reclamation. Many of these are shown in Figure 4.1 and include; source separation and separate collection of recyclable materials; energy recovery from wastes by incineration, production of refuse-derived fuel (RDF), pyrolysis; composting; hydrolysis and fermentation to produce alcohol or proteins; and mechanical separation of recyclable materials.

Fig 4.1 WASTE MANAGEMENT OPTIONS FOR DOMESTIC WASTE



For further discussion of these processes see Thomas (1979); Porteous (1977); Bridgewater and Mumford (1979); WMAC (1978); Skitt (1979), USBOM (biannual); USEPA (1975-9); MRI (1973a); NCRR (1974).

A major question with regard to these waste utilisation methods is whether the waste materials are kept separated from each other throughout or whether they are mixed together for collection, then separated. Many of these developments are not intended as complete waste management systems, but as components of one. For example, a waste management system could comprise the following:

- source separation and separate collection of waste paper;
- mechanical recovery of glass and ferrous metal;
- production of RDF;
- controlled tipping of the remaining fraction.

Compatibility problems have sometimes arisen however when these individual waste utilisation techniques are put together in an integrated waste management system. Two schools of thought have developed, one representing the so-called 'high' technology approach, and the other the 'low' technology approach. The former rejects source separation primarily on the grounds of inconvenience to the public, expected lack of participation, and the cost of separate collection, and concentrates on the problem of recovering materials and energy from mixed refuse. Development of mechanical separation techniques and energy recovery from waste, known collectively as 'Resource Recovery' are the main focus of research in this direction. In their Annual Reports to Congress, the US Environmental Protection Agency (USEPA, 1975-9) describe the growing investment both by Government and private industry

in that country in Resource Recovery. Seldman (1980) reports that public funding for Resource Recovery amounted to 500 million in 1977. The National Centre for Resource Recovery (NCRR) (1980) reviewed the extent of development and adoption of Resource Recovery in the US, describing a total of 41 plants.

Increasing attention has also been focussed on these technological solutions to resource recovery in Britain in recent years. A Department of the Environment research station, the Warren Spring laboratory, has been developing a variety of mechanical separation equipment, as well as conducting some work on pyrolysis; see Douglas and Birch (1976), Warren Spring Laboratory (1976), and Douglas et al (1974). There has also been a number of developments in the production of RDF (refuse derived fuel) by both local authorities and industry. Two Waste Disposal Authorities (WDAs), South Yorkshire County Council and Tyne and Wear County Council, received government assistance to build Resource Recovery plants designed to offer limited material recovery by mechanical separation, and to produce RDF. Imperial Metals Industries, and Blue Circle Industries have also both established RDF plants, using municipal waste.

The Waste Management Advisory Council (WMAC) (1978) describes developments in the use of waste as a fuel, including RDF, incineration and pyrolysis in Britain. It concluded that up to almost eight million tonnes a year of municipal waste could be burned as RDF, leading to coal savings of up to three million tonnes a year.

The other approach to waste utilisation, known as source separation, is based on the premise that different recycled materials should be kept as separate and uncontaminated by other waste products as near

the source of arising as possible. Source separation of recyclable materials should produce a higher quality of reclaimed material, and eliminate the need for complex and costly separation equipment.

Source separation is defined by USEPA (1978) as:

"the setting aside of recyclable waste materials at their point of generation for segregated collection and transport to specialised waste processing sites or final manufacturing markets. Transportation can be provided either by the waste generator, by city collection vehicles, by private haulers and scrap dealers, or by voluntary recycling or service organisations."

Advocates of source separation emphasise the greater potential energy savings realised through recycling waste materials over their use as fuel, and consider that recycling maximises the value of the waste material through these and other environmental benefits. Wilson (1979) shows that the net energy yield achieved by the production of RDF per tonne of waste processed in a Resource Recovery plant (such as that in the Tyne and Wear) is 4,000 MJ, compared with 5,322 MJ saved by dry sorting and recycling the paper contained in the same tonne of waste.

The source separation approach relies essentially on devising systems of storage, collection and processing of separated waste materials. The technologies employed are generally less complex, and hence cheaper than that for Resource Recovery. Source separation relies on household participation, and hence becomes an educational and social problem as much as a technological one.

Source separation is usually seen as the first step in a waste management system subsequently employing one or more of the following:

- energy recovery;
- mechanical separation;
- composting;
- incineration and landfill.

Although there are not necessarily any problems in this approach major conflicts have arisen in the USA, where both source separation and Resource Recovery operate on a wider scale than in Britain. Predictably, much of the conflict stems from the allocation of money for research and development.

Source separation advocates argue that investment in Resource Recovery plant programs has soaked up all available funds to the exclusion of serious development of source separation schemes. Seldman (1980) maintains that in 1977, in the USA, 8% of post-consumer waste was recycled by source separation whilst only 1% was processed in Resource Recovery plants, despite a roughly \$5 million to \$500 million disparity in public funding of these respective technologies.

Another problem increasingly arising in the USA comes from competition between energy recovery and recycling of waste. Resource Recovery plants are often designed without taking into account the possibility of prior source separation of recyclable materials. In order to protect heavy capital investment, the resultant plants are required to be run at their rated capacity. This conflict has led in some areas of the USA to written contracts or legal restrictions limiting moves towards either reducing waste (such as packaging controls) or recycling them.

The seeds of such a conflict exist in Newcastle due to the Tyne and Wear County Council Resource Recovery Plant. Operating experience is demonstrating that the water content of mixed household refuse is too high for satisfactory production of RDF pellets. This problem is presently overcome by mixing this 'wet' waste with waste from commercial premises which has a very high paper content. If the latter, and indeed some of the domestic waste paper, were removed for recycling the plant could run into problems.

Resource Recovery is still a relatively new and unproven technology with many plants being first generation or prototypes, or still at pilot plant stage. Frequent failures and escalating costs has led to investment in these systems being increasingly questioned. Source separation has therefore been gaining recognition and increasing, if still limited, support in the USA. In California, over two hundred cities have recycling centres and twenty have a separate collection scheme. The Department of Environmental Quality's Recycling Switchboard in Oregon lists over three hundred reclamation schemes. Cohen (1979) undertook a survey for the US Environmental Protection Agency in 1977, which identified two hundred and five separate collection programmes in the USA.

It is difficult directly to compare source separation schemes with Resource Recovery plants, as the former do not deal with all the household waste produced, only the recyclable materials, so that another waste management option is necessary to deal with the remaining fraction. Source separation schemes however are often considered more appropriate to a community industry approach to reclamation and recycling. Source separation schemes in general are less capital intensive and more labour intensive.

The environmental benefits of source separation are greater too; energy, resource and pollution savings all derive from recycling in preference to burning wastes. Source separation schemes tend to process much smaller amounts of waste than Resource Recovery plants, and to serve much smaller communities. This approach hence facilitates a greater degree of community-based organisation of reclamation and recycling, through the establishment of a decentralised network of local reclamation centres or schemes, leaving the remaining fraction of the waste to be either processed by a more centralised Resource Recovery plant, or disposed of by landfill.

The following sections therefore will concentrate on the source separation approach to reclamation, as that considered more appropriate to community or neighbourhood based reclamation schemes.

4.2 RECLAMATION IN BRITAIN - THE CURRENT SITUATION

Statistics produced by the Society of County Treasurers, County Surveyors Society and Chartered Institute of Public Finance (SCT, CSS and CIPFA) (1980) show that only 1% of the 25 million tonnes of household and commercial wastes collected in 1987/9 by local authorities in Britain were reclaimed and recycled. Paper accounts for the largest proportion of this reclaimed waste, and is estimated by the British Paper and Board Industry Federation (BPBIF) (1980) to approximately total 200,000 tonnes reclaimed annually. Other materials reclaimed by local authorities include metals (50,976 tonnes in 1978-9; the majority of this being ferrous metal, largely comprised of tin cans) and small amounts of rags, glass, compost and fuel. In addition to those wastes reclaimed by local authorities ought to be added those wastes reclaimed by individual households, voluntary/charity groups, gypsies and 'rag and bone' or scrap merchants. In 1974 as estimated

by WMAC (1976) voluntary/charity reclamation schemes collected 200,000 tonnes of waste paper. The figure is probably much lower today. Unfortunately little data exists to quantify these sources.

Waste paper is also the material reclaimed in Britain on the most significant scale through source separation. Operated both by local authorities and voluntary/charity groups, source separation schemes for reclaiming household waste paper are organised in a variety of ways. The majority of local authority schemes involve the collection of waste paper, separated from other refuse by the householder, either at the same time as the other refuse (ie, in a trailer or specially adapted vehicle) or as a separate collection. Some voluntary/charity groups operate collection schemes, others rely on householders to bring their waste paper to a collection point. The latter is known in the US as a 'drop-off' centre. Turner (1981) cites one such scheme operating in Croydon, Surrey, using local schools as the drop-off centres. Once a month, parents and children bring their waste paper to the school and place it in a large container left by a local waste paper merchant.

Both separate collection schemes and drop-off centres are employed in reclaiming other materials from household wastes, although not as widely as for waste paper. Some local authorities have collected rags as well as waste paper in the past, although I am not aware of any continuing this practise. A few local authorities including York City Council, West Yorkshire Metropolitan Council, Staffordshire CC, and the Royal Borough of Dunfermline have been known to experiment with the collection of separated waste glass. The York City pilot scheme in 1974 received most attention, primarily in analysing its lack of success, see York City Council (1974) and Bate (1976) for further details. It was found that the price of collection did not nearly

meet the high collection costs involved. Close examination of the figures, though, shows that in terms of the weight of glass separated, public response was good, and that if smaller reusable sacks had been used for collection, hence significantly reducing the operating costs, the scheme might have made a profit.

Since 1978 reclamation of household glass has taken a different turn with the growth of the Bottle Bank concept. Essentially, a bottle bank is a drop-off collection point for glass cullet (rather than bottles), and members of the public are asked to deposit waste glass bottles and jars into a container. Environmental Data Services (ENDS) (1979) state that there were over 350 bottle banks in Britain, leased or bought by local authorities from the Glass Manufacturers Federation, each collecting about 70 tonnes of glass per annum, in that year.

Collection point systems are also used to collect waste sump oil from motorists and to collect aluminium. Currently many local authorities provide containers at some of their Civic Amenity sites for motorists to bring waste oil to, also some garages provide collection points for waste oil. These provisions however are generally poorly advertised. A survey of motorists carried out by Over (1979) in the Surrey/Hampshire area found that 65% did not know where their nearest legal disposal point was, although 80% were aware that certain methods of disposal were illegal.

It is illegal to dump waste oil in public sewers, drains, natural waters, or disposed of on land (except where specifically authorised). These legal restrictions, imposed because of the pollution problems caused by dumping waste oils, provide the main incentive to local authorities to provide collection points.

Once collected, the oil can be recycled by re-refining back into lubrication oil, or cleaned for use as a fuel. Thomas (1979) maintains that only about 15% of the half million tonnes of waste sump oil generated per annum is reclaimed and recycled.

The use of Civic Amenity sites for waste oil collections suggests their potential use for further reclamation activities.

Keith Woodhouse (1979) points out that 15%-20% of all domestic wastes are now taken to Civic Amenity sites; 3 million tonnes per annum. He proposed that they could deposit both 'bulky wastes' and recyclable materials in special containers; in fact, very much along the lines of US drop-off centres.

Aluminium foil has been collected by charities, such as 'Guide Dogs for the Blind' for many years, but in the last three years other aluminium reclamation schemes have sprung up. In 1978 Oxfordshire County Council and the Oxfam Wastesaver project set up a scheme using schools and community centres as collection points for aluminium foil.

Buckinghamshire County Council also launched a pilot aluminium collection scheme the same year as reported by Solid Wastes (1978), in which schoolchildren collected aluminium scrap and placed it in specially provided plastic sacks.

All aluminium cans, and aluminium-top drinks cans are another source of scrap aluminium for recycling. In Edinburgh in 1979 Alcoa launched a scheme called 'cash-a-can', described by Turner (1981). Voluntary collectors were paid 1p for every all aluminium can taken to one of a number of collection points. These were collection lorries parked for three hours at selected sites in the city each week. In Leeds a

similar scheme 'catch-a-can' was launched in 1980 by the voluntarily organised 'Save Waste and Prosper' scheme. This scheme described in Materials Reclamation Weekly (MRW) (1980, 1981) is based on skips and bins at over fifty collection points throughout Leeds, 'catch-a-can' is designed to collect both aluminium and tinplate steel cans for recycling.

The majority of tin-plate steel cans, and other ferrous metal in household waste, are however recovered magnetically from other refuse. Magnetic separators are often employed at transfer stations, at incinerators or composting plants. Of the 2 million tonnes of ferrous metal in household waste, every year only some 50,000 tonnes are recovered. Some work has been done to improve the recovery of 'tin' cans from refuse by Materials Recovery Ltd, with a view to improving the quality of separation. The method they have developed is described in MRW (1977) and employs cryogenic fragmentation (ie, cooling in liquid nitrogen before fragmentising) separation.

Magnetic separation of ferrous metals apart, very little mechanical recovery is carried out by local authorities. As mentioned before two resource recovery plants in South Yorkshire and Tyne and Wear are now operating, incorporating some of the mechanical recovery techniques developed at the Government's Warren Spring laboratory (see Thomas, 1979 for further details).

A few local authorities still incorporate some manual separation, ie, hand-picking recyclable materials from mixed refuse on a conveyor belt, although many more have, in the past, as the following quote from the Local Authorities Management Services and Computer Committee (LAMSAC) (1975) shows:

"Forty years ago a few local authorities were almost totally recycling the materials collected as refuse. They were producing clinker asphalt, clinker paving slabs, clinker for fill, animal feed, ferrous and non-ferrous metals, glass in the form of cullet and bottles and jars sorted for return to the distributors, textiles suitably graded, paper cardboard suitably sorted and baled, and heat by steam for driving plant, heating baths and wash houses and generation electricity. Most of the sorting and processing was dependent on manual labour, of which there was a surplus."

The Worthing Hygiene Unit in West Sussex is one of the best known local authority reclamation schemes in Britain, and well documented by Gosling (1970 and 1973). Waste paper and textiles were collected pre-separated, ferrous metals magnetically separated, and other salvagable items, paper, rags, non-ferrous metals, bones, felt, and sacking, removed by hand on a picking belt. The residue is either composted or incinerated. Unfortunately, when West Sussex County Council assumed responsibility for disposal, much of this scheme was curtailed for financial reasons. By 1981 Worthing only recycled waste paper, and glass through a Bottle Bank.

Other reclamation from household waste that takes place in Britain is carried out either by or for the benefit of charities, or in the case of the more valuable wastes, such as non-ferrous metals, car batteries and scrap cars, by individual householders, scrap merchants or gypsies.

Charities operate a number of different levels from boy scout groups collecting waste paper, 'jumble' sales (an important source separation

activity, which cannot easily be quantified) to more ambitious reclamation projects, some of which are trying to create employment as well as to provide environmental benefits or to raise funds.

The Oxfam 'Wastesaver' Scheme, which ran from 1975 to 1978, is probably the most well-known and studied of the latter group, although not the only scheme of this type to have existed or existing today. Wastesaver was established as a community-based recycling centre collecting source separated waste from households, and to act as a collection point for materials brought in. They recycled paper, glass, tin cans, aluminium, textiles, clothing, furniture and electrical goods, and employed eighty people. In 1978 the scheme was essentially wound up due to financial losses (see Section 4.2.2)

In Leeds the Recycling for Charity Committee runs the 'Save Waste and Prosper' scheme, which reclaims almost as wide a range of materials as Wastesaver, that is, waste paper, glass, old clothes, waste car oil, aluminium cans and foil, and 'tin' cans. This scheme, though, is entirely voluntarily run and operates by means of fifty collection points throughout Leeds, where householders bring their waste materials and place them in a variety of skips and bins, including twenty Bottle Banks. Waste merchants and charities collect the materials once a month. The scheme described by MRW (1980 and 1981) recycled 1298 tonnes of domestic waste in 1979, and raised £7,642 for charity. Other multi-material reclamation schemes include the Community Support Anti-Waste Co-operative in Cardiff, which employed eight people, in 1981.

Another organisation that has ventured into setting up reclamation centres and community-based recycling schemes, is the Friends of the Earth, (FOE). FOE's interest in recycling springs from a concern for

environmental quality, and resource and energy savings. Through a network of local groups, FOE campaigns to increase public awareness of the problems of waste and benefits of recycling. Some local FOE groups began practical action on these issues and started waste paper, and sometimes bottle, collections for recycling. Out of these beginnings have developed a handful of more ambitious schemes, including Oxford FOE who operate a scheme using a converted milk float to collect paper and jumble. Some groups developed their waste paper reclamation into a business, such as Southampton FOE who set up the Phoenix Recycling Co-operative which employed three people in 1981.

This completes a brief review of the wide range of reclamation activities in Britain. In describing the variety of approaches taken in reclaiming household waste, it is important not to lose sight of the fact that in total these schemes still reclaim only about 1% of the total household wastes produced. The following three sections describe local authority waste paper reclamation schemes, Bottle Banks and the Oxfam Wastesaver scheme in more detail.

4.2.1 Local Authority Waste Paper Recovery

Britain was the first country in Europe to adopt local authority reclamation schemes. As described by Wray and Nation (1977), ^{the numbers of local} authorities involved in waste paper recovery has changed considerably over the years. It reached a peak in wartime, and in particular in 1942, when local authorities collected 433,000 tonnes. In 1973/4 around 50% of local authorities ran waste paper reclamation schemes, collecting about 300,000 tonnes, or 17% of the total waste paper recovered in the UK that year. The BPBIF (1980) estimated that in 1979 local authorities collected around 200,000 tonnes, just 9% of the total waste paper recovered in the UK that year.

A survey undertaken by the Department of the Environment in November 1974, indicating which collection methods are most widely used, is cited by Wray and Nation (1977). Of 187 local authorities in England operating permanent collection schemes in 1974 for collections from domestic premises, 47% used trailers attached to refuse collection vehicles on normal refuse collection rounds, 20% used separate vehicles and 5% used both, while 21% did not operate a scheme covering domestic premises. For commercial or trade premises, only 8% used trailers, 70% separate vehicles and 19% used both.

Some local authorities provide containers or sacks for the separated waste paper, whilst the majority rely on householders to bundle and tie their paper or stack it in boxes ready for collection. Attempts have been made to evaluate economically these variations in collection method only to highlight a strong dependence on local factors, such as population density, traffic and terrain conditions. Although this makes universal generalisations difficult, it has led to the development of a standard accounting procedure to help local authorities evaluate what is appropriate to their particular area, (see DOE (1976)).

LAMSAC (1975) showed that the average amount of waste paper recovered per week in a local authority collection scheme is 1.5 kg per household co-operating, where one in three households co-operates. They also estimated a figure for collections from trade premises of approximately 0.2 tonnes per week per 1,000 population.

The major problem faced by local authorities in respect of waste paper recovery, though, does not lie with the organisation of the scheme, or with public participation, but with the instability in the waste paper market. Table 4.1 shows the fluctuations in this market from 1952-75.

Table 4.1 INSTABILITY OF WASTE PAPER MARKETS 1952-1975

The following diary shows the waste paper demand fluctuations local authorities had to live with over the last 20 years.

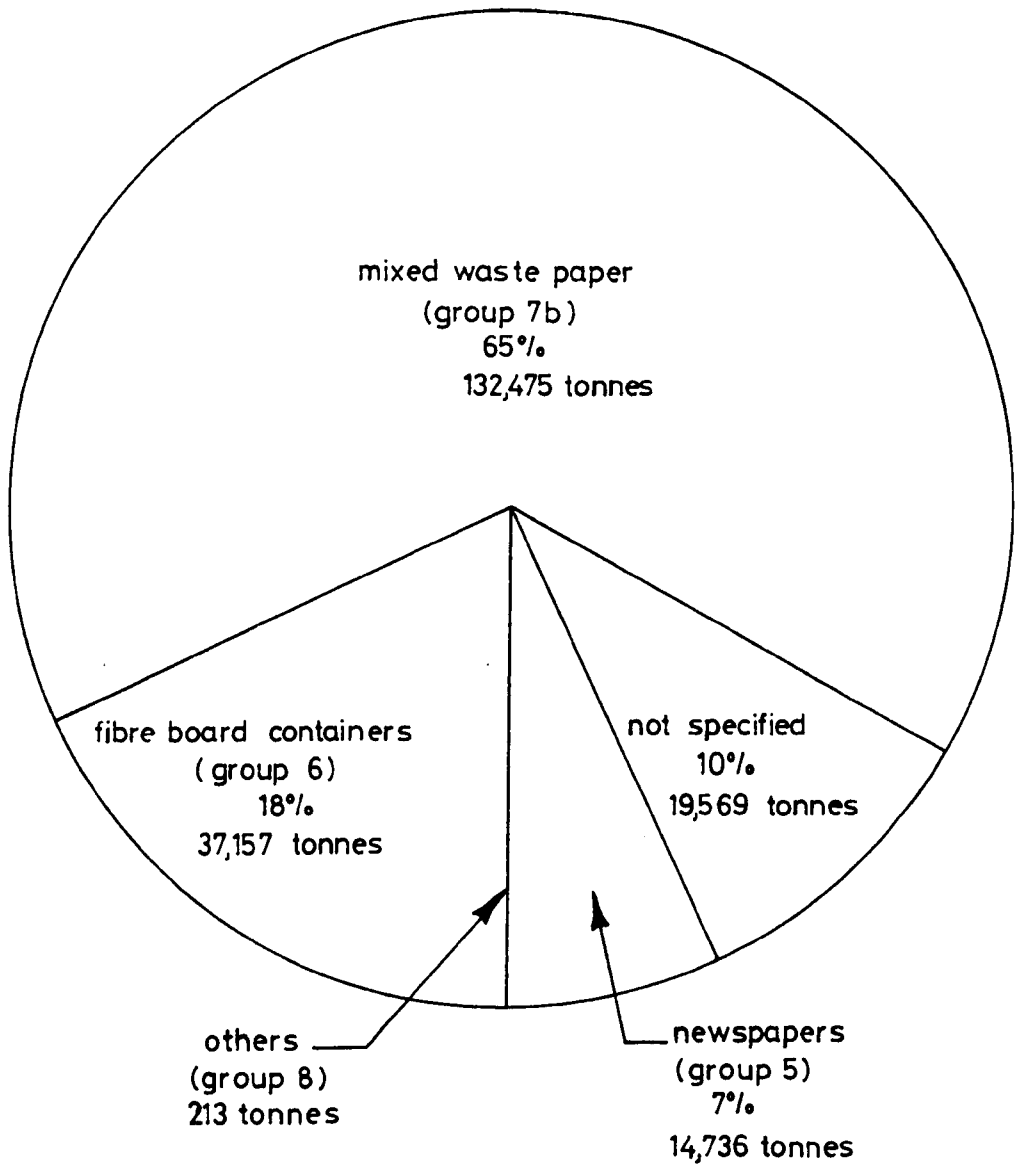
1952	Paper mills ask local authorities to relax waste paper deliveries voluntarily as they face a surplus of 100,000 to 150,000 tonnes per annum.
1953	May - restrictions relaxed. Autumn - mills seek increased supplies.
1954	National publicity campaign to increase tonnages.
1956	July - mills impose quotas reducing local authority tonnages by 8 per cent.
1957	Autumn - quotas slightly relaxed.
1958	July - quotas relaxed on mixed wastes
1959	September - all quotas removed.
1962	June - quotas imposed reducing deliveries by 12 per cent.
1964	October - quotas removed.
1967	April - local authorities asked to mark time.
1968	Increased tonnages sought.
1969	Publicity for increased tonnages in selected areas.
1970	Publicity continued.
1971	Quotas imposed and maintained on an increasing scale.
1972	Autumn - quotas relaxed.
1973	June - 250,000 additional tonnes asked for to meet demand until Autumn 1974.
1975	Quotas imposed.

Source: Thomas (1977a)

Unpredictable short-term fluctuations in demand for waste paper have discouraged local authorities from operating reclamation schemes, as they are, in general, unable to decrease the supply of waste paper they collect at short notice, and storage is expensive. A number of government committees (including the Waste Management Advisory Council's

Fig 4.2 WEIGHT OF PAPER COLLECTED BY LOCAL AUTHORITIES
IN ENGLAND AND WALES, 1974

Showing: Waste paper type and group.
Weight collected in 1974, in tonnes, and as
% total of 204,150 tonnes.



Source: DOI (1975)

Waste Paper Recycling Working Party) and research projects, as well as the paper industry and local authorities themselves have sought a solution to this problem, with no apparent success.

Waste paper collected by local authorities is primarily of the lower quality grades, with the bulk being mixed waste paper or grade 7b (see Fig 4.2). The major markets for these grades of waste paper are in the packaging and building industries. Both these sectors of the economy are very sensitive to changes in economic activity, and are the major cause of the sensitivity of the waste paper market. This suggests that widening the range of uses made of low grade waste paper could have a stabilising influence on this market.

4.2.2 Bottle Banks

The Bottle Bank glass recycling scheme was launched in August 1977 in Oxford and Barnsley, and grew to over three hundred and fifty Bottle Banks all over Britain by 1981. ENDS (1979) concluded that each Bottle Bank collected an average of 1.32 tonnes of cullet per week; this totalled 24,000 tonnes from all Bottle Banks in 1979, or just over 1% of glass container production.

ENDS (1979) also estimated that 250,000 people participate by bringing waste glass bottles and jars to the Bottle Banks. Participation rates are difficult to estimate accurately for this type of reclamation scheme, but a population response rate was estimated, as the percentage of the total amount of waste glass available in the area that is collected through Bottle Banks. This varied from a top of 28% in Colwyn Bay to 1.6% in Glasgow. Response rates are shown in Table 4.2 together with other data giving an indication of the extent of the scheme in June 1979.

Most of the Bottle Banks in use are specially designed skips or containers, most with a capacity of 4 tonnes of glass. Most of these containers have wood lined interiors to reduce noise, and partitions to keep brown, green, and clear glass separate. Bottle Banks are leased or bought by local authorities, who are then responsible for emptying them, storing waste glass or cullet until they have an economic load of 20 tonnes or more, and transporting it to a glass works.

Distance to the nearest glass works plays an important part in the economics of a Bottle Bank scheme, because of relatively high transport costs.

Table 4.2 BOTTLE BANK STATUS CHECK (JUNE 1979)

Area	No Skips	No Weeks In Operation	Collected in June (Tonnes)	Average Collected /Week/Skip (Tonnes)	Response Rate
Oxford	7	96	69.27	1.78	23.8%
S. Yorkshire	6	96	40.03	1.22	n.a.
Scunthorpe	2	95	6.61	0.66	3.8%
Colwyn Bay	5	84	22.80	1.06	27.9%
Chelmsford	3	63	40.48	2.62	27.6%
Northampton	6	54	50.74	1.59	14.3%
York	4	50	19.78	1.20	10.1%
Brigg	1	50	2.39	0.62	21.7%
Edinburgh	5	43	52.05	2.10	4.8%
Leeds	6	42	41.01	1.42	3.6%
Stirling	4	40	4.97	0.39	7.3%
Falkirk	4	34	7.21	0.43	5.2%
Kirkaldy	4	34	*11.00	0.62	6.6%
Bolton	5	33	26.45	1.35	8.4%
Restormel	2	33	* 5.00	1.23	6.9%
Cheltenham	5	31	31.19	1.26	17.7%
South Ribble	4	28	*21.00	1.15	16.2%
Colchester	4	28	32.36	1.60	16.8%
Reading	5	13	64.71	2.49	18.7%
Glasgow	7	13	30.68	0.95	1.6%
Chorley	3	10	5.70	0.63	11.3%
	92				

Monthly Total: 585.43 tonnes
 Total Tonnage: 5831.07 tonnes
 Average of 1.32 tonnes/skip/week

* Figures approximate

Source: ENDS (1979)

The Glass Manufacturers Federation were reported by MRW (1978) as suggesting that 150-200 miles from a glassworks might be the economic limit for a scheme to be viable (ie, not cost the local authority money). The number of skips in an area, and tonnages of glass collected also affect the economic viability of Bottle Bank schemes. The Glass Manufacturers Federation (GMF) have produced a formula to help assess this which is described by Turner (1981). In Table 4.3 the costs per tonne of cullet handled by two successful Bottle Bank schemes are outlined, showing a profit of £1.59 in Oxford and £1.45 in Colwyn Bay.

Table 4.3 BOTTLE BANK SAMPLE OPERATING COSTS, 1978

Costs per metric ton:-

<u>Oxford</u>	£	<u>Colwyn Bay</u>	£
Skip handling at £5.50 per load	3.25	Skip handling at £9 per load	4.43
Site maintenance at £5 per load	2.96	Miscellaneous labour costs	1.50
Bulk transport	3.70	Loading at £5 per load	0.62
Total running cost	9.91	Bulk transport	3.50
Paid by glassworks	11.50	Total running cost	10.05
Profit to council	1.59	Paid by glassworks	11.50
Further saving in disposal cost	1.52	Profit to council	1.45
Average skip load - 1.69 metric tons		Average skip load - 2.03 metric tons	
Six sites		Five sites	

Source: MRW (1978)

4.2.3 Oxfam Wastesaver Scheme

The Wastesaver scheme was designed to serve a dual purpose for Oxfam; as a fund-raising venture, and to demonstrate that industrial nations not only consume an excessive proportion of the world's resources but waste much of it. The Wastesaver Centre was established in Huddersfield in 1975, and developed around the concept of collecting household wastes separated at source.

A derelict textile mill was converted into a recycling centre, making extensive use of donated equipment and money. Machinery was installed for processing paper, tin cans, aluminium, textiles, glass and plastics, all of which were collected from local households, and some other collection points. Textiles were sorted into six grades to fetch

higher prices. Paper was fed by conveyor into a continuous hydraulic press that produced 1 kg bales. These were loaded by fork-lift truck onto articulated trailers, and production reached about 20 tonnes a week. Packaging cartons were fed down to the basement through a chute and were dealt with by a box baler.

Ferrous material, glass, aluminium and plastics were carried forward by conveyor, and the next stage was removal of ferrous metals (mainly in the form of tin cans) by magnet. Granulation reduced this metal to small flat chips for sale to Batchelor Robinson's de-tinning plant on Teeside.

Thereafter, hand-sorting took over. Glass bottles of unusual shape were extracted for sale in the shop upstairs as lamp bases; others on which deposits were payable were also removed, and the remainder were thrown into a series of bunkers according to colour for eventual sale as cullet to Redfearn National Glass of York.

Markets were found for baled plastic containers for use in the manufacture of weatherproof boarding, and for clean polythene film which could be granulated and made into a variety of new products. Oxfam had an agreement with Alcoa for aluminium disposal.

The small percentage of waste left, which it was not possible to reclaim, was carried away by the local council for incineration.

The Wastesaver centre also incorporated what was then believed to be the biggest charity shop in the world. Here second-hand clothes (inspected and dry-cleaned or washed) and reconditioned furniture,

electrical appliances, repaired and tested in the centre's own workshop, and books and gifts were sold.

Household collections were tried out in a number of different ways. First the 'Dumpy' was distributed to 6,000 contributing households. The 'Dumpy' was a tubular steel stand which held four plastic sacks, into which householders were asked to separate their reclaimable wastes, with different materials going into different colour sacks. Red for newspapers, yellow for mixed paper, blue for jumble rags, silver paper and aluminium, and white for clean tin cans, glass bottles and jars. Larger items and cardboard were put out separately. Collection was carried out by a team of twelve operating from four vans.

Household response to these regular, monthly collections as analysed by Blackmore (1978) was good, with between 50% and 70% of households issued with 'Dumps' participating. In general, yields of around 9 kg of paper, 6 kg of glass and tin cans, and 1.5 kg of textiles, were achieved per household per month. However the Dumpy system was expensive to operate, and suffered design problems in that it tended to blow over in high winds and this the system was abandoned in 1977. It was replaced by three other experimental systems:

- (i) Monthly collections of paper and textiles, separated by householders into plastic sacks, placed inside a green plastic bin. Yields analysed by Blackmore (1978) were 3.5 kg of textiles and 7.5 kg of paper per household per month.
- (ii) Three-monthly collections of paper and textiles.
- (iii) Fortnightly collections of paper only.

Unfortunately all of these house to house collection systems ran at a financial loss, calculated to be at an average of £3 per tonne of waste collected, Blackmore and Turner (1978). Other approaches to waste recovery were also tried, including collections from a local hospital and polytechnic, and a cardboard collection from a local market. Collection or drop-off points also played a minor role in Wastesaver, with one point in Wastesaver's own car park, and another a converted railway truck in a supermarket car park. The final method of recovery used was through Oxfam's national shop network and links with other collecting charities.

Gradually, due to financial pressures, more and more of the collection activities of Wastesaver were abandoned. The scheme cost around £400,000 for its first two years, and after three years it was effectively closed down. Instead of developing as a community-based recycling centre, Wastesaver transformed itself, after three years, into a nationally-based textile and aluminium recycling business.

Blackmore and Turner (1978) carried out a detailed cost-benefit analysis of the Oxfam Wastesaver scheme, which concluded that in 1978 the overall Wastesaver scheme made a private profit of £100,000, due entirely to the profits from aluminium and textile reclamation and the Wastesaver shop. Much of this was as a result of national Oxfam collections of aluminium and textiles. Household collections however made a loss in that year of £4,000 (or £3/tonne of waste collected). This loss, in respect of the locally based recycling activities of the Wastesaver scheme, was considered by Blackmore and Turner (1978) to have important implications for local recycling centres generally. They concluded that:

"on private cost and benefit terms local recycling centres are unlikely to be profitable."

However if the analysis is extended to include social costs and benefits a different picture emerges. Again Blackmore and Turner (1978) concluded that Wastesaver achieved a net social economic benefit, even in respect of house-to-house collections. The private loss of £4,000 in 1978, associated with the latter activity becomes a social benefit of £12-17,000 (or £10-£14 per tonne) when the social costs of employment benefits in an area of high unemployment are taken into account. Wastesaver employed around eighty people in 1978.

4.3 COMMUNITY SOURCE SEPARATION SCHEMES IN THE USA

Many of the source separation schemes in the USA are community-based projects, run as profit or non-profit (or charitable) businesses, with a minority run by municipal authorities. Many started as voluntarily-run projects up to ten years ago, gradually building up from processing a few tonnes a month to hundreds of tonnes a month, employing a full-time staff of up to twenty or thirty people. Many still rely on some voluntary help, and most of the schemes on government subsidies for providing employment. Some organisations, however, manage to be economically self-supporting.

The more established of these schemes process between 20 and 2,000 tonnes per month of recyclable materials. These include newspaper, cardboard, waste office paper, glass cullet, reusable bottles, aluminium and steel-based cans, other metal scrap, oil, car batteries, clothes, some plastics, and even food waste for compost. These reclamation groups serve communities ranging from 500 to 100,000 households. However these figures are deceptive in that many of the larger schemes

are secondary recycling organisations, which act as processing depots and marketing organisations for a number of small reclamation centres, either run by the central group or by independent groups. The average size of individual recycling centres or schemes is more probably under 100 tonnes per month.

These community based source separation schemes are documented in a number of publications, mostly written as guides to setting up a recycling programme. These include Mulligan and Powell (1979), CSWMB (undated), Fresno County EOC (1979), Recycling Information Office (1977), Berkeley Ecology Centre (undated) and the Association of Bay Area Governments (undated).

It is not really possible to cite a typical reclamation centre or project, as each one has unique features. However, there are distinct types of source separation schemes and projects which are representative of the range found in the USA, and which fall into three categories:

- drop-off centres;
- buy back;
- collection schemes.

4.3.1 Drop-Off Centres

As the name implies, these are centres where recyclable materials can be dropped off, or left, by the public. A centre can be permanent, temporary or mobile; staffed or not; open twenty-four hours a day, or only specified hours and days. It can be simply a storage area or incorporate some processing as well. This type of scheme requires members of the public to separate particular recyclable wastes and bring them to the centre, thus requiring a fairly high degree of

motivation. A centre may accept only a single material (eg, waste newspaper) for recycling, or more commonly, a range of materials.

The Californian Solid Waste Management Board (CSWMB) (undated) produced some economic data based on typical (or model) centres of different types. Of particular interest was a break-even point in terms of tons per month handled by a centre above which it could make a profit. This was put at 25 tonnes a month for a drop-off centre, assuming some voluntary and some paid labour. This compares with 135 tonnes per month for a buy-back scheme, and 600 tonnes per month for curbside collection. Drop-off centres are often the first step in a recycling operation, which later grows into collection, or simply expands through a large network of drop-off centres. However, as will be shown later, this progression in 'economic' size is not always reflected by actual projects with collection schemes processing 20 tonnes per month operating successfully alongside drop-off schemes receiving 700 tonnes per month.

a) Portland Recycling Team

In 1980 the Portland Recycling Team, were in Portland, Oregon, running a project which is predominantly a network of drop-off centres, but which also acted as a processing and marketing organisation for other reclamation groups. PRT began as a single item drop-off programme in 1970, recycling about 10 tonnes per month, and in 1980 recycled a wide range of materials amounting to about 700 tonnes per month. It had seven permanent drop-off centres and a centralised warehouse for storage and processing, and operated seven trucks, two transits, a forklift truck and a paper baler. PRT, a non-profit company, employed in 1980 sixty people in the equivalent of thirty full-time jobs. It also ran collection programmes from commercial premises and offices, and handled, transported and marketed, reclaimed materials, as well as undertaking

some of the education and publicity work, for nearly thirty community projects such as schools, churches, and scout troops (for 50% of the resultant income).

In early 1980 PRT were reclaiming waste glass, newsprint, mixed or scrap paper, office waste paper, tin cans, aluminium, some plastics, and waste motor oil. Table 4.4 shows their monthly average quantity and revenue of each recyclable material for 1979.

Table 4.4 PORTLAND RECYCLING TEAM RECORD FOR 1979

Material	Tonnes/month	Revenue/month
Glass	320	\$10,332
Newsprint	158	4,166
Mixed paper	88	770
Corrugated card	53	2,556
Office paper	44	4,238
Tin cans	31	996
Aluminium	0.6	2,253
Motor oil	(700 gall)	
Total	694.6	\$25,320

Source: Mulligan and Powell (1979)

The income from sale of materials covered about 70% of the expenses of PRT, the other 30% is made up by grants, (particularly through employment subsidies from government) and other sources.

b) Arcata Community Recycling Centre

The majority of, although not all, drop-off centres are non-profit organisations, able to receive, and in many cases, dependent on government grants. The Arcata Community Recycling Centre in Northern California is a typical example. Although now 70% self-supporting and reclaiming 115 tons per month in 1980, ten out of their thirteen and a half full-time jobs were paid for by government or state employment subsidies (Arcata Recycling Centre, 1980). The centre operated as a drop-off centre and processing warehouse. They also had a number of mobile centres, bought wastes from other charities and operated some office collections. Their equipment in 1980 comprised three trucks, a forklift, and a paper baler, as well as storage containers; and they collected the same range of recyclables as PRT.

The availability of markets with adequate prices is obviously an important factor in the viability of any recycling scheme. Despite considerable fluctuations in market conditions, up to May 1980 few groups in the USA seemed to have had serious trouble finding buyers for most of the materials they were collecting. An indication of this is that Arcata is three hundred miles from its nearest waste paper buyer and yet still collected and sold waste paper.

4.3.2 Buy-Back Schemes

Buy-back schemes are based on the principle that recyclable materials are bought processed and sold for recycling. They are usually organised around a reclamation centre where people bring their recyclable materials. The centre must be staffed to receive, weigh and pay for materials brought in. Payment can be cash or in the form of donations to local charities. A buy-back centre will usually only pay for the higher value materials, although they will often accept

(but do not pay for) other materials as well. On the whole, buy-back schemes tend to be more profit-orientated than Drop-off Centres and are often run as for profit businesses. They also need to be of sufficient size to support the staff necessary for dealing with the public.

a) Seattle Recycling

Seattle Recycling in Seattle, Washington, handled 150 tonnes of materials plus 15,000 returnable beer bottles per month in 1980. It operated both a central warehouse depot, and a mobile centre. Niece (1980) described the operation as employing eight full-time and four part-time workers, and having a considerable amount of processing equipment, including paper balers, magnetic separator for cans, scales, forklift and other trucks. At that time they bought back returnable beer bottles, newspaper, tin cans, aluminium and other metals, and office paper, and will accept also motor oil and glass. About 60% of their \$30,000 revenue from sales per month went to the public in payment for materials brought in (1980 average figures). This scheme appeared to operate successfully in a good market situation.

b) Ecolohaul

The market situation is also good in Los Angeles, where Ecolohaul recycled 2,000 tonnes per month in 1980 through a network of buy-back and drop-off centres. Seven of these centres were run by Ecolohaul, with many others using its services for transport and marketing.

4.3.3 Collection Schemes

Collection schemes range from regular weekly or monthly to occasional or one-off collections; they can be door-to-door household or business, commercial or industrial routes; they can be combined with the collection of other wastes or separate; and they can involve the collection of one or more recyclable materials. They are more convenient to householders or businesses who are only required to separate out recyclable materials, and either put them out with other refuse or on a different day for collection.

In a survey done in 1978 of two hundred and eighteen separate collection programmes by Cohen (1979), only forty schemes collected more than one material. Nearly all the schemes were run by municipal authorities, with only 29% run by private firms, and the other 12% by community organisations. A separate collection vehicle was used by the majority of schemes (72%), with others using racks and trailers, and a few (just 2%) using compartmentalised vehicles.

Separate collection schemes can be expensive to implement and run, and hence generally require considerable throughput to run economically. This explains why such a large proportion are run municipally.

CSWMB (undated) concluded that below 600 tonnes per month, a collection scheme would not break even; however smaller schemes do exist, as the following examples show.

a) Montclair Recycling

Montclair Recycling in Montclair, New Jersey, is at first sight an example of a collection operated successfully with relatively small throughputs of materials. It recycled about 100 tons a month of waste

paper in 1980 through a curbside collection, and a drop-off centre. The drop-off centre also recycled about 40 tons a month of aluminium and glass, (see MOC, undated).

The project was run jointly by the town authorities and by a volunteer citizen group, Montclair Organisations for Conservations. MOC ran a drop-off centre, open Saturdays only, to receive newspaper, magazines, glass, aluminium and returnables. The newspaper and magazines were passed on to the Town of Montclair Recycling Department, which operated a curbside collection programme. Curbside refers to the fact that members of the public put separated newspapers out at the curb for collection. MOC's recycling centre not only contributed 40% of the total paper collected, but also subsidised the curbside collection scheme, as the figures in Table 4.5 show. This highlights the economic problems of making a small collection scheme pay for itself.

Table 4.5 MONTCLAIR RECYCLING, REPORT FOR 1978

Income		Expenses		Profit
<u>Town of Montclair</u>				
Newspaper and Magazines	\$42,943	Operating Expenses	\$44,159	- \$1,216
<u>MOC</u>				
Revenue from Recyclables	\$18,485	Operating Expenses	£1,619	+ \$16,866
Gross Income	\$61,428			+ \$15,650 (total profit)

Source: MOC (undated)

b) Portland Collection scheme (proposal)

Participation in separate collection schemes might be expected to be higher due to the greater convenience to householders than drop-off centres. However, comparison is difficult because of the problems of estimating the populations served by drop-off centres and hence their participation rates. The USEPA's survey of separate collection programmes carried out by Cohen (1979) found the majority to have participation rates of 20% to 49% of householders covered. In areas, though, where it was mandatory to separate recyclables, participation rates of 50% or more were more common.

In a report prepared by Resource Conservation Consultants Inc, (RCC) (1979), they proposed a model for a city-wide separate collection scheme for Portland, Oregon. They concluded that a 35% participation rate was reasonable to expect, and on this basis calculated that 1 ton per month per 67 participating households (or 200 total households) of recyclables could be expected, if tin can, aluminium, glass and newspapers were being collected.

The proposed scheme was based on 40,000 participating households from an area of 115,000 households, and involved a separate collection of recyclables using eleven trucks with eight trailers and a workforce of thirty-eight. The summary budget (Table 4.6) shows a net loss of \$356,456, or an annual cost per household of \$3.12. If this figure is less than the cost of alternative methods of disposal then the scheme can be considered viable. Unfortunately this comparison is not made in this study.

Table 4.6 SUMMARY BUDGET FOR PROPOSED PORTLAND COLLECTION SCHEME
(FIRST YEAR)

Cost	Revenue	Revenue	Balance (Profit/Loss)
Equipment	\$ 86,436		
Labour (34 workers)	\$395,269		
Administrative, Sales and Publicity (4 workers)	\$183,530		
	<u>\$665,235</u>		
Sale of recyclables		\$308,779	
Net Program Loss			\$356,456

Source: Resource Conservation Consultants (1979)

c) Garbagios and Cloudburst

There are a number of successful multi-material collection schemes less ambitious than that proposed above for Portland in operation in the USA.

Garbagios, in Eugene, Oregon, was operating as a garbage collection co-operative. A consumer owned company, and run by the workforce, in 1980 they collected garbage (or refuse) and recyclables from 750 households in a specially converted truck. Garbagios had five paid and two voluntary workers, and they collected paper, clothes, glass, aluminium, tin cans, other metals and compost, (Garbagios, 1980).

Cloudburst, another small garbage collection company, operating in Portland, Oregon. It employed two people in 1980 who collected 20 tons per month of recyclables, and 45 tons of other waste from 650 households, (Cloudburst, 1980).

Table 4.7 SUMMARY OF SELECTED COMMUNITY-BASED RECLAMATION PROJECTS IN THE USA, 1980

Project	Years in Operation	Type of Project	Materials Recovered	Tons per Month Reclaimed	Number of Employees	Financial Basis	Profit or Non-profit Organisation	Equipment Used
Arcata Community Recycling Centre	9	Drop-off centre + collection from offices, shops + university + buy back (from charities) + mobile centre	Paper - office, newspaper, card Glass, tin cans aluminium, metals, reusable containers, oil	115	13½	3½ employees on own payroll + 10 paid by government grants, 70% self-supporting	Non-profit	3 trucks 1 forklift 1 baler
Portland Recycling Team	10	4 Drop-off centre + buy back from charities and other centres + some collection	Paper - office, newspaper, card Glass, tin cans aluminium, metals, reusable containers, oil	695	30 full time equivalent	85% self-supporting	Non-profit	7 trucks 1 baler 2 transits
Cloudburst	5	Curbside collection - collect waste & recyclables from 650 households	Paper - office, newspaper, card Food scraps, Glass, tin cans aluminium	20	2	rely on collection fees	-	1 truck 1 trailer

Freemont	6	Curbside from 2000 households + drop-off centre	Newspaper, aluminium, glass, reusable bottles	80	12	3-4 on own staff	Non-profit	2 trucks
Rainbow Recycling		Drop-off centres 4 or 5	Aluminium, newspaper, reusable bottles	120	4-5 some part-time		Profit	1 truck
Seattle Recycling		Buy-back + mobile centres, 6 sites monthly	Reusable bottles glass, aluminium paper, tin cans motor oil, car batteries, metal	150 + 1500 beer bottles	8 full + 4 part-time	Sales of \$30,000 per month	Profit	Balers, forklift truck, aluminium separator, scales (bottle washer)
Bring		Drop-off - mobile and permanent	Glass, tin cans paper, metal aluminium	60	5		Non-profit	1 truck 1 glass crusher
Garbagio	2	Curbside-collect garbage and recyclables from 750 households	Organics, paper clothes, glass, metal, tin cans aluminium		5 paid (2) (vol)		Co-op consumer owned worker run	1 truck
Richmond	10	Drop-off - 2 full time centres and 7 Saturday only centres	Paper, glass wine bottles tin cans, metal aluminium	100	Vol and part time	Government employment subsidy	Non-profit	

Santa Barbara	6	Drop-off centre + buy back from charities, + Curbside collect (paper). + Air force base centre	Office and news-paper, glass. tin cans, metal aluminium	400	5 full 3 part time		Non-profit	2 trucks can crusher
Ecolohaul	8	Buy back + Drop-off centres (7 + marketing for others	Paper, glass oil, tin cans aluminium metal	2000	20	Gross over \$1 million per annum	Non-profit	Magnetic separator and blower trucks containers
Long Beach	10	Drop-off centre + collection (on campus and OAP home)	Paper, glass oil, tin cans aluminium	90	10 part time	self-financing		2 trucks
Palos Verdes	10	Drop-off centre (run by county)	Newspaper, tin cans, glass aluminium	165	2 full + 4 part time			
Montclair	9	Drop-off centre + collection for newspaper - (10% collected this way)	Paper, glass aluminium	141	3 full + 1 part time + vol	self-financed (subsidised by vol)	Non-profit	1 truck 2 vans

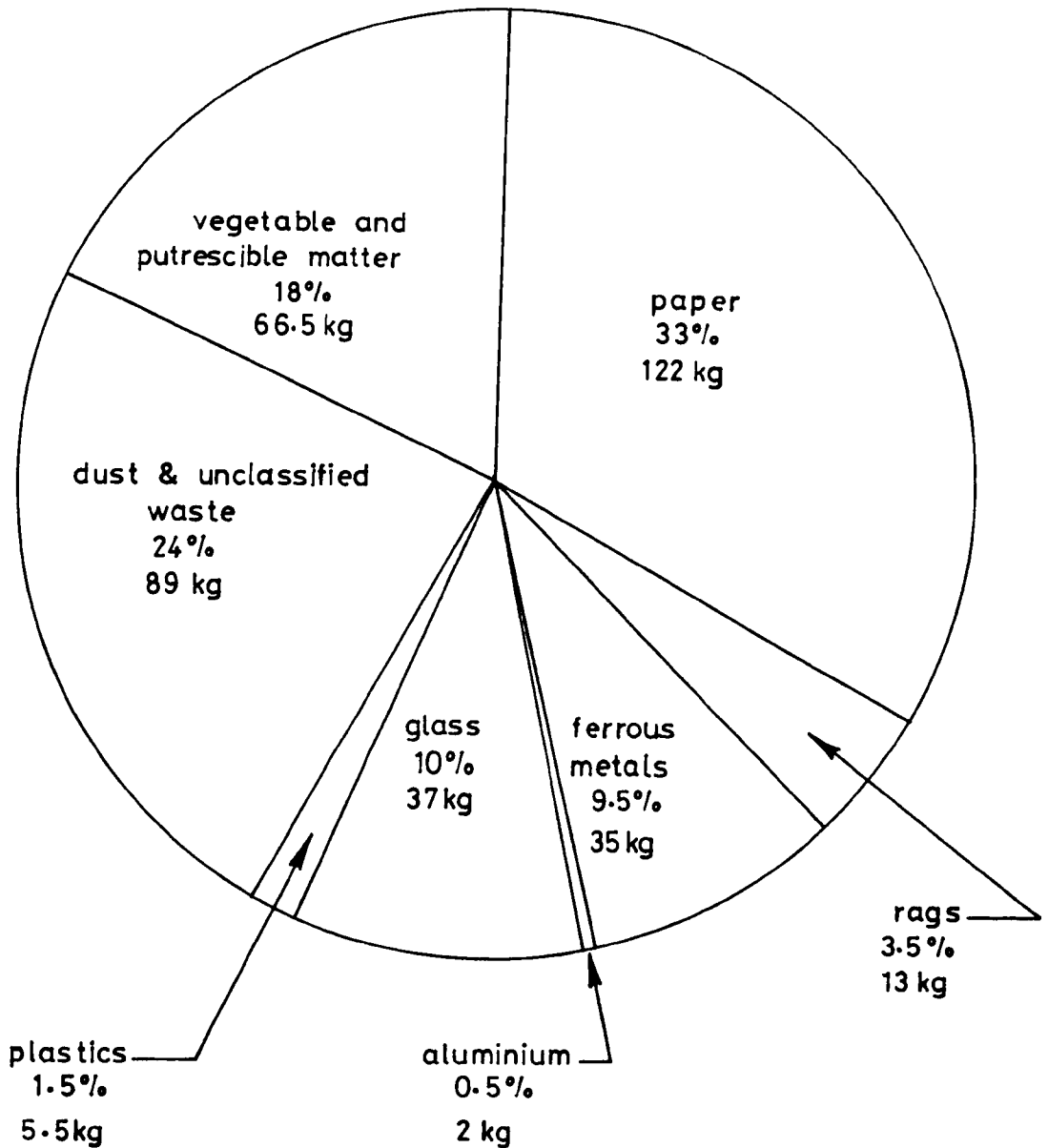
4.4 MODEL SYSTEMS FOR 'COMMUNITY' SCALE RECLAMATION

4.4.1 Waste Generated by Neighbourhoods and Communities

National average statistics concerning amounts of domestic waste produced are compiled annually by the Society of County Treasurers and the County Surveyors Society and the Chartered Institute of Public Finance and Accountancy. From SCT, CSS and CIPFA (1980) the quantity of domestic waste per person per annum was calculated at 0.37 tonnes for 1978/9. The composition of these wastes is shown in Fig 4.3.

Fig 4.3 COMPOSITION OF DOMESTIC WASTE

Showing: % composition by weight (1973)
 Weight per person per annum (1978/9)
 (Total domestic waste/person = 0.37 tonnes)



Source: Waste Disposal Statistics, 1978-9

A neighbourhood with a population of between 100 and 1,000 people would therefore be likely to generate between 37 and 370 tonnes of domestic waste per annum; and a community between 370 and 3,700 tonnes per annum. Therefore for an average sized neighbourhood of five hundred people, and an average sized community populated by five thousand people, the amounts of waste generated would be 185 and 1850 tonnes per annum respectively. The composition of these wastes is shown in Table 4.8.

Table 4.8 THE AVERAGE QUANTITY AND COMPOSITION OF WASTES FROM NEIGHBOURHOODS AND COMMUNITIES

Domestic Waste arisings/annum	Neighbourhood (tonnes)	Community (tonnes)
Vegetable and putrescible matter	33.3	333
Paper	61.05	610.5
Metal	0.9 AL) 17.6 FE) 18.5	9.0) 176.0) 185
Rags	6.47	64.7
Glass	18.5	185
Plastic	2.77	27.7
Dust + unclassified wastes	44.4	444
Total (in round figures)	185	1850

These figures are for domestic wastes and correspond to current consumption patterns. Industrial wastes will depend entirely on the mix of industrial/manufacturing activities carried out in the neighbourhood or community and without detailed knowledge of this they cannot realistically be included in this analysis.

National average statistics, however, cannot give a very accurate picture, since domestic waste composition has been found to vary considerably from area to area, Skitt (1972). It is therefore important to analyse the waste arisings in a particular neighbourhood or community before considering their reclamation. It is also important to look at just what each of the categories of material in Fig 4.3 and Table 4.8 consist of, in order to more accurately determine their potential for reclamation and recycling. For example, Thomas (1979) states that about half of the paper found in refuse is packaging materials, and the rest is newspapers and magazines. Virtually all the glass, metal and plastics in refuse are packaging materials; bottles and jars, 'tin' cans, aluminium cans and foil, and the wide variety of plastic wrappings and containers. Vegetable and putrescible wastes are self-explanatory, but may vary from area to area, dependent on the number of households who compost these wastes.

4.4.2 Participation in Source Separation Schemes

Participation rates have been much easier to assess for collection schemes than 'drop-off' or collection point projects, due to the difficulties with the latter of estimating the population served. Considerable variation has been found in participation rates from scheme to scheme, as summarised in Table 4.9. All the areas covered in the table have collection schemes, except for Norwich and Blackburn, where no comprehensive or local authority collection schemes exist, but householders recover considerable quantities of waste paper voluntarily, or for charity.

Table 4.9 shows participation rates from as low as 15% to above 60%, and giving an average of 35%. Participation rate is defined as the percentage of households covered in a collection scheme that participate

Table 4.9 PARTICIPATION RATES AND MATERIAL YIELDS PER HOUSEHOLD
IN SOURCE SEPARATION SCHEMES

Area (and date)	Type of Source separation scheme	Participation rate %	Yields of Materials per participating household per annum
Waltham Forest (1969)	Waste paper collection weekly	26-34	224-254 kg paper
West Bromwich (1969)	Waste paper collection	15	224 kg paper
Worthing (1970)	Waste paper collection	23-35	192-218 kg paper
Middlesbrough (1974)	Waste paper collection fortnightly	15-55	354 kg paper
Oxfam Wastesaver (1976)	Mixed material collection monthly	42-65	109 kg paper, 72 kg glass and 'tin cans' 18 kg textiles
Wastechaser (Teeside) (1977)	Waste paper collection	15-40	163-272 kg paper
Norwich	None except voluntary or charity collection of waste paper	63	N/A
Blackburn	None except voluntary or charity collection of waste paper	41	N/A

Source: Blackmore (1978) and Turner (1981)

by separating their wastes. LAMSAC (1975) suggests that for local authority waste paper recovery a participation rate of 33% might be expected. A participation rate of 35% is assumed by RCC (1979) in the proposed model for a city-wide separate collection scheme for Portland, Oregon, USA, based on US experience.

It is often argued that house-to-house collection schemes will give higher participation rates than 'drop-off' or collection point systems, because they are more convenient for the participants. Mercer, Lowther and Chapman (1980) argued this point, citing as evidence the greater participant response to returning milk bottles compared with practices in returning other beverage bottles.

A wide variety of factors affect the participation rates experienced in reclamation schemes, with those most commonly referred to being education and income levels of population, frequency of collection or location and density of collection points, and the amount of publicity a scheme is given. The report on a survey of separate collection programmes in the US, undertaken by Cohen (1979) for the EPA, indicates a significant relationship between participation rates and mean income and median education level of residents in areas where such programmes operate. Evidence from USEPA (1976 and 1978 b) of two demonstration recycling programmes, in the Sommerville and Marblehead communities in Boston confirm the importance of income and education to participation levels. Sommerville, an urban, blue collar area recycled only 8.1% of its residential waste in 1977, whereas Marblehead, a suburban white collar area, achieved a 30% recycling rate.

Other attempts to examine participation in source separation schemes have concentrated on the reasons for participation.

Kuylen and Van Raaij (1979) emphasised the importance of the psychological make-up of the householder, and suggests three types of recycler:

- 1 Social recyclers, who feel recycling is socially desirable, for example, to abate litter, or reduce the dangers to refuse collectors from broken glass;
- 2 Ecological recyclers, who are concerned about energy and resource issues;
- 3 Economic recyclers, who stress the importance of cost savings.

Non-recyclers, though, did not seem to fit into such clear categories. O'Riordan and Turner (1979), in their survey of Norwich, found both the economic and ecological motivations common.

There seems to be some general agreement that publicity and information campaigns are important in both encouraging and sustaining participation in source separation schemes, whether house-to-house collections, or based on 'drop-off' points. SVA (1978) maintain that the location and density of the latter, as well as the capacity of the containers, are considered to exert a significant effect on participation. With collection schemes, it is maintained that the frequency of collection most influences participation by both SVA (1978) and Cohen (1979).

4.4.3 Yields of Recyclable Materials

LAMSAC (1975) suggest that a yield of a minimum of 1.5 kg of waste paper per week per participating household could be expected for local authority waste paper recovery schemes. This represents only 23% of the total of 6.4 kg of waste paper available; and amounts to 78 kg per year. They state that this figure was tested out by reference to eight operating schemes; however, it differs considerably from the

average yields shown for the schemes represented in Table 4.9. These give average yields for participating households of just under 200 kg of waste paper per annum, which is 60% of the total available.

It would, therefore, seem sensible to expect yields somewhere between these two figures. The actual yield achieved will depend on the same variety of factors as those affecting participation rates, described in Section 4.4.2.

Considerably less information is available on the yields of materials other than waste paper, collected through source separation schemes. Oxfam's Wastesaver centre, when operating monthly multi-material collections, was achieving yields calculated as a percentage of the total available in refuse of 36% for glass and tin cans, and 51% for textiles. Recovery rates have been calculated by ENDS (1979) for glass cullet reclaimed through Bottle Banks, and vary between 1.6% and 28% of that available in domestic waste available in the areas in which they are sited.

These figures all refer to yields of a specific reclaimed material in relation to the total amount of that material available in domestic waste. It is also useful to consider the overall yield of reclaimed material from a source separation scheme in relation to the total amount of domestic waste. For the Oxfam Wastesaver scheme, the total amount of recyclable materials collected per household in 1976 was 198 kg, or 20% of the total domestic waste available. It is worth noting that Wastesaver only achieved a fairly low yield of 33% for its waste paper recovery. Combining the Oxfam wastesaver results for glass, tin cans and textiles, with a more optimistic yield of 60% for waste paper recovery, would give an overall yield of materials reclaimed of 29%.

4.4.4 Economics and Employment

It is extremely difficult to generalise about the costs and profitability of source separation schemes, due to the considerable importance of specifically local influences. Some attempts have been made to define a minimum economic size for different types of reclamation systems, such as CSWMB (undated) and by LAMSAC (1975) in evaluating local authority waste paper recovery schemes. These results however cannot be generalised, and only have meaning within very narrow constraints.

Mercer, Lowther and Chapman (1980) stressed in their report that reclamation schemes must take into account factors such as the demographic structure of the population, its mobility and cultural background. These, plus the frequency of collections, or location, density and capacity of collection points, will all affect the economic of a reclamation scheme, as will the availability of markets and the prices paid for the waste materials collected. Transport costs also play an important role, since they are very high relative to the value of most secondary materials.

Employment generated by source separation schemes is another aspect which has attracted considerable attention, but about which it is again extremely difficult to generalise. The US community based source separation projects described in Section 4.3 and Table 4.7 can be seen to employ one person for every 0.35 to 3 or more tonnes of waste collected per day. RCC (1979) suggest that the proposed scheme for Portland should employ one person per 0.67 tonnes per day of reclaimed materials collected.

Employment aspects of British reclamation projects are less well documented, with the exception of Oxfam's Wastesaver, and the Teeside Wastechaser paper recycling scheme. Analysis carried out by Blackmore (1978) and Blackmore and Turner (1978) shows that Wastechaser employed one person per 0.2 tonnes of waste paper collected per day, and Wastesaver employed a collection team of twelve to reclaim 1228 tonnes per annum, giving 0.3 tonnes of materials per person per day. (The latter figure, though, makes no allowance for sorting and processing staff at the Wastesaver centre.) Both these schemes however were found to be uneconomic, and were abandoned after a few years operation.

4.4.5 Reclamation Opportunities for Neighbourhoods and Communities

Working from the calculated waste arisings for neighbourhood and communities, and making assumptions about the likely household participation rates and yields of recyclable materials, it is possible to calculate how much a source separation scheme might reclaim. Table 4.10 summarises two such calculations. In these a participation rate of 35% and yields of (1) 20% and (2) 29% have been assumed. The 20% overall yield is that achieved by the Oxfam Wastesaver scheme, and represents a 33% yield of available paper, 36% of both glass and metals, and 51% of textiles. The higher overall yield of 29% represents a higher yield of 60% for waste paper recovery, together with the same yields of 36% for glass and metals, and 51% for textiles. These figures were considered representative of the range of results practically achieved by source separation schemes in Britain.

Table 4.10 PROJECTED YIELDS OF RECYCLABLE MATERIALS FOR
NEIGHBOURHOOD AND COMMUNITY SOURCE SEPARATION PROJECTS

	Total Domestic Waste (tonnes pa)	Projected yields of materials from source separation scheme (in tonnes pa)			
		(1) low yield		(2) high yield	
Neighbourhood (pop 500)	185	12.95	paper 7.05 glass 2.35 metals 2.35 textile 1.20	18.70	paper 12.80 glass 2.35 metals 2.35 textile 1.20
Community (pop 5000)	1850	129.5	paper 70.5 glass 23.5 metal 23.5 textile 12.0	187.0	paper 128.0 glass 23.5 metal 23.5 textile 12.0

Note: (1) represents 35% participation rate and 20% yield of materials.

(2) represents 35% participation rate and 29% yield of materials.

An average sized neighbourhood of 500 people would therefore be likely to collect between 13 and 19 tonnes of recyclable materials per annum through a multi-material source separation scheme; and an average sized community of 5,000 people between 130 and 190 tonnes per annum. Comparing these figures with the expected yield per person employed in such a scheme gives the following results. Yield of reclaimed material per employee was discussed in section 4.4.4, and shown to vary from 0.2 to 3 (or more) tonnes per day. Even at the lower end of this scale, assuming 0.2 tonnes per day or just under 50 tonnes per annum per person, it is apparent that a neighbourhood would be too small an area to support such a source separation enterprise. A community of 5,000 people however might provide work for between two and three people for reclaiming its wastes, assuming this low figure of 0.2 tonnes per day per person. Yields of 0.2 and 0.3 tonnes per person per day were found by the Oxfam Wastesaver and the Wastechaser schemes to be

uneconomic. Higher yields should be aimed at to provide a viable economic basis for a source separation scheme, such as between 0.5 and 2 tonnes per day per person as commonly found in US source separation schemes.

Assuming 0.5 tonnes per recycler per day (or 120 tonnes per annum) then a community source separation scheme could only support one - two recyclers. Yields of around 2 tonnes per person per day would involve larger scale source separation schemes, probably at a district scale. A community would not be large enough to support a scheme achieving this high a yield per employee. These figures are speculative however, as they are not based on a full economic analysis of reclamation schemes but only on the experience of a few such projects and the employment levels they managed to support.

It is interesting to compare these results with the ORE system, a model proposed by Duncan (1975). The ORE system consists of a network of community reclamation centres. (These are referred to as neighbourhood centres by Duncan.) They each serve five hundred participating households (ie, total population of fifteen hundred households, or four thousand people) and employ four people. These centres are in turn served by a number of district reclamation centres, each employing six people, and serving twenty community reclamation centres, would be able to undertake marketing functions, and further processing for the smaller community reclamation centres and possibly directly recycle some wastes themselves.

As described the ORE system would probably not be economically viable in Britain, although the model could have potential for the development of community based reclamation and recycling in Britain. The above

analysis indicates that community source separation schemes may be of sufficient size to support 4 people in full-time employment. Although in order to be economically viable they may require higher yields per person employed, and hence likely to provide only one - two full-time jobs. District source separation schemes would seem to have a greater potential viability. Economic advantages may also accrue from a network of reclamation schemes, over individual schemes, such that a wide network of community reclamation centres could be established served by a smaller number of district reclamation and recycling centres.

CHAPTER 5

'COMMUNITY' SCALE RECYCLING

In this chapter the potential for developing recycling activities on a 'community' scale using domestic waste materials, is investigated further. Section 5.1 reviews the 'community' scale repair, renovation, reuse and recycling activities that exist in Britain today, giving a brief overview of the type and range of small enterprises engaged in these activities. Then section 5.2 attempts to determine the size of community to which these recycling processes and enterprises can be considered most appropriate.

The benefits of a Community Technology approach to recycling are discussed in Chapter 1, and focus on the environmental impact effects and the compatability of recycling processes with developing community self-reliance. 'Community' scale decentralised recycling also offers advantages over larger-scale, centralised recycling in view of the dispersed nature of domestic waste arisings, and hence the resultant high transportation costs associated with the latter.

Another issue often raised in discussion of 'community' scale enterprises concerns economies and diseconomies of scale of the processes involved. One example of diseconomies of scale in a recycling process occurs in the paper industry, as described by Western, a retired chief executive of Reed Engineering and Development Services, and consultant to the Intermediate Technology Development Group (ITDG) (Western 1979a). Over the past seventy years, the size of paper-making machines has increased from approximately 2 metres in width to 10 metres; operating speeds from 100 metres per minute (m/min) to 900 m/min, and annual

productive capacity from 5,000 tonnes per annum (t/a) to over 150,000 t/a (that is, from 15 tonnes per day (tpd) to over 400 tpd). Western (1979a) maintains that increasing size has been outpaced by increasing cost, and that concern has developed within the industry that the desirable maximum has been exceeded and diseconomies of scale have crept in. He shows that the intrinsic cost of (paper) machines per unit of production increases disproportionately above a given width and still further above a given speed. These cost increases are not compensated by increased sophistication, and reduced materials and ancillary plant costs, because of the greater volume involved. The inflexibilities of large plant also creates inefficiencies in matching production to demand in a fluctuating market.

The relatively low value of many reclaimed materials relative to transport costs, makes the latter a significant factor in the economics of reclamation and recycling. Considering the widely dispersed nature of household waste arisings, it becomes apparent that large scale, more centralised recycling activities will suffer a penalty from increased transport costs. This is supported by the conclusion reached by Klein et al. (1978), in a feasibility study of small-scale cellulose insulation industry in Tompkins County, New York:

"Transportation energy is the second largest factor (in energy conservation; the first is choice of raw material) favouring a decentralised industry such as cellulose (insulation manufacture) which would use fifty times less energy in transport compared with a highly centralised insulation industry."

5.1 'COMMUNITY' SCALE RECYCLING ACTIVITIES IN BRITAIN - THE CURRENT SITUATION

The following review of community scale recycling (including repair, renovation, reuse and recycling) activities in Britain, and including some examples from the USA, demonstrates that a significant amount of activity exists amongst small businesses.

Section 5.1.1 and 5.1.2 give an indication of the range of repair and renovation and reuse businesses currently found in Britain. A comprehensive survey of these activities has not been attempted; just to give examples of each type of activity cited. These are taken from three recently published directories of co-operatives in Britain:

Co-ops: a Directory of Industrial and Service Co-operatives: Co-operative Development Agency (CDA) (1980).

Directory of Common Ownership Co-operatives: Industrial Common Ownership Movement (ICOM) (1980).

In the Making: an annual directory of co-operative projects.

The development and extent of community based co-operative activity is fairly well documented in these and other publications. The same is not true of the small privately owned firms and businesses, carrying out recycling activities, about which little information is currently available, and which probably far outnumber co-operatives.

Section 5.1.3 looks in greater detail at some specific examples of community scale recycling activities, involving the manufacture of goods from waste materials. The emphasis in this section falls on developments in recycling technology and opportunities for increasing community scale recycling, rather than on existing recycling activities. The reason for this is that relatively few community scale manufacturing recycling businesses exist today.

5.1.1 Repair and Renovation

(a) Furniture renovation

The past ten years has seen a considerable growth in small businesses carrying out furniture renovation, including re-upholstery work and stripping down and renovating furniture made of wood. This commercial sector, found in almost any town, is fringed by groups who have taken up this activity as a job creation or community service activity. Pearce and Cassidy (1980) describe one such project, 'Goodwill', in Glasgow, established by the Council for Voluntary Service. It employed thirteen people in 1980 in a workshop to collect, refurbish and sell discarded furniture, as well as clothing, bric-a-brac and books. Goodwill was set up to run as a financially self-sufficient venture, although initially with the support of Manpower Services Commission (MSC) money. It intended to provide employment for disabled people, alcoholics and ex-mental hospital patients.

(b) Consumer appliances

Repairing electrical and other consumer appliances is an activity which is predominantly carried out in the community by individuals

(often in an informal way) and by small shops and businesses (often as a sideline activity). Some large manufacturers offer repair services for their products, but increasingly product design is such that repairs can cost more than replacement. This situation is exacerbated by the lack of availability of spares for many appliances making repairs more difficult; a form of built-in obsolescence, described by Packard (1963).

The repair of consumer appliances, especially electrical goods, has formed the basis for the development of a number of community based businesses, including the following two examples. The Oxfam Wastesaver scheme (described in more detail in section 4.2.3), included an electrical goods repair shop, where discarded appliances were repaired and tested before resale in the Wastesaver shop. Brass Tacks, in the East End of London, employed twenty people on MSC funding in 1980 in a community workshop for recycling unwanted electrical appliances and furniture. The project, set up by the Mutual Aid Centre in April 1980, sells the repaired items in its shop, the profits going to local charities. It also offered a repair service, as well as help, to individuals wanting to carry out their own repairs.

(c) Buildings

Building renovation and repair is another area dominated traditionally by small businesses. Many small building firms undertake repair and renovation work, some as a deliberate policy, others because it is work offered. In recent listings of co-operative buildings groups in CDA (1980) and In the Making (1980/81), six co-operatives are mentioned as specifically concerned with renovation repair and

refurbishing work. Action Area Builders, Altham Workers, Co-op, Artemis, Bristol Community Building Co-op, Experimental Community Workshops, Keskidee Building Co-op. These are all small businesses, employing between two and ten workers, and represent only a very small proportion of building firms, both co-operative and private businesses, that engage in this type of work.

(d) Vehicles

Cycle repair has supported the development of some small businesses in recent years due to a revival of interest in cycling. Both Recycles in Edinburgh and York Cycleworks, are small co-operatives combining cycle hire with repair work. Recycles opened in 1977, just doing cycle repair work and have since expanded and switched their emphasis for economic reasons to cycle hire. In 1980 they employed about six people, hiring bikes, selling bikes and spares, and doing repairs.

The majority of car repairs are also carried out by small businesses, whether by garages, individuals, or repair firms. Again this area has seen a growth in community based activity, with a few vehicle repair co-operatives emerging. The Metropolitan Motor Cab Co-operative repairs taxis and cars and Major/Minor Repairs in Leeds, repairs and renovates Morris Minors which are themselves 'long-life' cars, designed for easy repair. The MKOK Garage in Milton Keynes is a motorist 'Do-it-Yourself' Repair Centre, which offers to members of the public the opportunity to carry out repairs to their cars in a controlled and well-equipped environment, with experienced mechanics on hand to give advice. Opened in 1979, it is a consumer co-operative, with over one thousand members.

5.1.2 Reuse

Repair and renovation could also be labelled as reuse, since a waste product is being made available for use again in the same form, or for the same function. This section considers two additional types of reuse activities which support small businesses.

Most reuse associated with the first group occurs within the home, business, or institution, not as a separate or distinct productive activity; for example, reusable linen, cutlery or crockery. In some cases though, the processing necessary for reuse to be possible is a distinct activity carried out by a separate business or industry. Bottle washing and laundering services are two examples of this, and both activities support some small businesses. A small number of bottle washing firms operate in Britain, buying in mostly wine and some screw-top bottles, washing and sterilising them for resale in the wine, beer and soft-drinks bottling industry.

An interesting example of a community based bottle washing business comes from California, USA, where the Berkely Ecology Centre started ENCORE, or Environmental Container Reuse. Described in *Compost Science/Land Utilisation* (1979), ENCORE predominantly washes wine bottles for which there is a large local market. ENCORE grew into a thriving small business employing around nine people in 1979, handling 20,000 cases of bottles a month (about 80 tonnes of glass), with a turnover of over \$125,000 per annum. Also recently incorporated into the process is an experiment in the use of solar energy to heat the water for washing.

Secondhand shops represent another example of reuse. Nearly-new clothing shops and secondhand goods shops and dealers, selling almost everything from cookers to cars, books to building materials, exist

today in most towns around Britain. In fact, they are so much a part of everyday life that they are often overlooked when considering recycling activities.

5.1.3 Recycling

Manufacturing goods from waste materials, or recycling, covers a very wide range of activities, including the production of papers and board from waste paper, the use of waste glass in producing glass fibre, re-refining lubricating oils, de-tinning tin-plated steel, and many others. However, the majority of these recycling activities are carried out in 'large-scale' centralised plants, and examples of community-based or small-scale businesses engaged in the manufacture of goods based on recycling are not very common.

This contrasts strongly with the substantial development of community-based, small businesses in reuse, repair and renovation, and poses the question of what has limited a similar growth in manufacturing recycling activities. Both the lack of appropriate technological development, and financial constraints, play major and interactive roles. However, in precisely what way the roles interact varies from activity to activity, such that a detailed analysis of each specific recycling technique is required before this question can be answered adequately.

Discussed below, under the headings paper, glass, plastics, metals, (referring to the material recycled rather than the recycling process), are examples of existing community-based recycling businesses, and technological developments considered appropriate to community-scale recycling activities. The following section on paper recycling contains considerably more information than those on glass, plastics or metals, reflecting the bias of this research, rather than the relative

importance of, or, indeed, scope for, recycling the different waste materials reclaimed from household wastes. Although paper, glass, plastics and metals account for the majority of household wastes, these categories do not cover all the materials that could be reclaimed from this source. One other important waste material not discussed below is textile wastes, or rags.

a) Paper

Waste paper can be recycled into a variety of products, with the most obvious and by far the most common being paper and board. Probably the next major use of waste paper is the production of insulating materials, including a loose fill cellulosic insulant and insulating wall-boards. Both these areas of recycling activity are described below. Other possible uses, not covered below, include shredding newspapers for animal bedding, animal feedstuffs, soil conditioner for land reclamation, peat block substitutes, artificial wood logs and roofing materials. Further discussion of these uses for waste paper can be found in CSAWS (undated) and Franklin (1973).

(i) Recycled paper and board: About 5% of the waste paper in household waste is currently recycled in Britain, in paper mills with production capacities between 20 and 200 (or more) tonnes per day. Recently there has been some interest in developing smaller recycling units, as a way of stimulating demand for waste paper and hence increasing its reclamation, whilst recognising the downward spiral that the UK paper industry is in. Facing a serious and continual decline through competition with pulp and paper mills abroad, the UK paper industry has, in many cases, found the capital investment of many millions of pounds in new large-scale recycling plant prohibitive.

A number of people and organisations have shown interest in the potential for community-based paper recycling, including the Wandsworth Employment Research Project, CAITS (the Centre for Alternative Industrial and Technological Studies, NE London Polytechnic), Leicester Inner Area 1 Youth Employment Committee, SE London SERA (Socialist Environment and Resources Association), Conservaction in Newcastle Upon Tyne, and the Childrens' Trash Bank in Ipswich.

A common scenario proposed by these groups involves using locally collected paper to produce a range of writing and drawing papers for use in local schools. It has been suggested that a move towards a more closed loop system in this way could reduce the quantity of wastes for disposal, whilst providing local employment producing for a local market.

Technically, a wide range of product output from 1 tonne per day (tpd) to hundreds of tonnes per day for recycling paper is feasible. However, the economic viability of the smaller production capacities is largely unknown, particularly for scales where the equipment is neither readily available nor in use in Britain today, and hence causing many of the important parameters in the financial analysis to be uncertain. This certainly applies to anything under 20 tpd.

Between 20 and 50 tpd capacity, although considered small scale by the British Paper Industry, has received some revived interest in recent years. However, the capital costs for a 20 tpd plant is still several million pounds, placing it beyond the scope of a community-based industry. An appropriate paper recycling technology for community-based enterprises, must therefore involve plant capacities of less than 20 tpd, probably much less, with much lower capital costs.

Some equipment is available that fulfils these criteria, but virtually all of it has been developed for Third World Countries, and hence its appropriateness for use in Britain is untried.

Pulp Packaging Units producing from less than 0.1 to 1 tpd of egg boxes or other moulded pulp products; a range of Indian paper-making equipment for plant capacities from 1 tpd to 15 tpd or more; and the 'Melbourne' plants producing much less than 1 tonne per week, are all examples of small-scale paper recycling plant operating in Third World Countries. Other designs have been considered, including a 5-12 tpd recycling plant designed but not built in 1975 by Allen W Berry Limited in conjunction with ITDG, and a 2 tpd plant designed by Parsons Limited, a paper machinery manufacturer in Manchester.

Capital costs of this equipment ranges from £1,300 for a 'Melbourne' plant to an expected £150,000 for the 2 tpd plant being developed by Parsons Limited. A 0.1 tpd Pulp Packaging Unit costs in the region of £50,000, and a larger unit producing around 1 tpd about £250,000. The Indian Coromandel Paper Plant costs around £20,000-30,000 for 1 tpd capacity. These figures show no overall correlation between the output and cost per unit output.

The Pulp Packaging Units were developed by Tomlinsons (Rochdale) Ltd, on behalf of Intermediate Technology Development Techniques Ltd, to satisfy a need in some developing countries where the total demand for egg boxes was smaller than that produced by other commercially available plant. Newsome (November 1978) describes the unit, designed to convert waste paper into egg boxes or trays, as comprising of modular machines of three types: a pulp preparation machine, a moulding machine and a product drying unit. By varying the mould shape, a wide range of

products can be produced, including fruit or meat packing trays, packaging for wine bottles, seed pots and insulating ceiling tiles (with the addition of fire retarding chemicals).

The other plants mentioned above produce either sheets or rolls of paper and/or board. The smallest scale production units are the 'Melbourne' range of paper recycling machines, which were developed by Anthony Hopkinson, and are marketed by 'Third Scale Technology' (3ST) Limited. (See 3ST (undated (a)), Hopkinson (1977), Hopkinson (1978) and Paper (1977).) They are sheet forming machines, with the 'Melbourne 5' producing sheets 600 x 420 mm suitable as writing, drawing or packaging papers. The 'Super Melbourne' produces larger but rougher quality sheets, 850 x 650 mm in size, and suitable only as packaging papers. Rated to produce between 60 and 100 sheets per hour, giving a maximum output of 0.04 tpd, they could both employ one two or three operators.

After experimenting for some time with a very small-scale continuous (Fourdrinier type) paper recycling machine, (MRW, 1979), capable of producing up to 0.5 tpd, Hopkinson abandoned its development due to both a lack of finance and technical difficulties, in favour of promoting an already proven design for a '1 tpd' plant, operating in India. The Coromandel paper plant (3ST, undated (b)) is a cylinder mould machine which can use a variety of raw material, including waste paper, to produce sheets of writing, printing and packaging paper, 1,110 x 660 mm. It is considered to require sixty to seventy-five workers to operate if run on a three-shift basis. Other similarly sized paper mills are to be found in India, many of which are hand-made paper mills, producing high quality papers, much of it for export.

Moving to a slightly larger scale, Western (1979 b), in his report on small scale paper-making in India, describes a typical 5 tpd recycling paper-mill. A continuous, Fourdrinier-type machine is used to produce writing and printing paper 1.25 m wide. It is estimated in the report that this type of mill would employ in India one hundred and eighty workers. A 15 tpd mill, using straw, rag and waste paper, is also described. Employing two hundred and sixty-five workers, this again is a continuous, Fourdrinier-type process. Both mills work a three-shift system. (It is not known whether these examples of small paper mills drawn from Indian experience could be operated by a smaller labour force in circumstances where labour costs were proportionally much higher than in India, such as in Britain.)

A British paper-machinery manufacturer, Parsons Limited, is reputed by Hopkinson (1981) to be developing a design for a paper-making plant with a capacity of approximately 2 tpd. The plant, a cyclinder-mould machine, is being designed for export to Third World countries. However, it will be more highly automated and hence less labour intensive than the Indian-designed plants, employing a total of twenty people (working a three-shift operation). Compare this with the Coromandel 1 tpd cyclinder-mould machine employing sixty to seventy-five workers - and two hand-made paper mills in India, one discussed by Western (1979 a) producing 0.25 tpd, employing one hundred and twelve people, and the other producing 1 tpd, employing ninety people, (Western 1979 b).

Insufficient data is available to assess the operating costs, and hence expected profitability of these plants. However, some tentative conclusions can be drawn from the information available. In Britain, the product value from a '1 tpd' paper-making plant, producing

writing/printing papers, would be in the region of £100,000 per annum. This is obviously insufficient to cover manufacturing costs and support sixty or more jobs, demonstrating that the Coromandel plant would not be an economically viable proposition in Britain. The Parsons '2 tpd' plant would produce approximately £200,000 of paper products per annum, which could, however, feasibly support twenty jobs, dependent upon the extent of manufacturing costs, other overheads, and capital depreciation. The output per employee of the Parsons plant is expected to be about 0.1 tpd/employee. This compares with an average of 0.2 tpd/employee in the British paper and board industry in 1979, a figure derived from data given by Barber (1981) on labour and productivity in the British paper and board industry.

Further research is required to investigate the economic viability in Britain of the Parsons plant. Similarly for the Pulp Packaging Units. Some years ago IT Development Techniques (1976) concluded, in an economic analysis of the UK operating costs for egg box production in their Pulp Packaging plant that, based on the market price of 2.55p per unit, a profit of up to 1.53p per unit, and a gross profit of over £400 per week were possible, at that time. What the position is today, though, is unclear.

It is useful to compare the capital investment per workplace of these paper recycling plants. This criteria was used in Schumacher (1973) as a definition of Intermediate Technology:

"If methods and machines are to be cheap enough to be generally accessible, this means that their cost must stand in some definable relationship to the level of income in the society in which they are to be used.

I have myself come to the conclusion that the upper limit for the average amount of capital investment per workplace is probably given by the annual earnings of an able and ambitious worker. That is to say, if such a man can normally earn, say, \$5,000 a year, the average cost of establishing his workplace should on no account be in excess of \$5,000. If the cost is significantly higher, the society in question is likely to run into serious troubles."

Capital investment per workplace for the Parson's plant will be in the region of £7,500. The £50,000 pulp packaging unit employs 5 people, giving a capital investment per workplace of £10,000. Both these figures are higher than the probable annual earnings of the workforce, but not substantially so.

However, a capital investment of £150,000, needed for Parsons plant, or £50,000 for the Pulp Packaging Unit, represent a relatively high investment for a community-based enterprise. This, then, poses the question of whether a smaller, cheaper plant could be operated successfully in Britain, independent of whether the Parson's plant or Pulp Packaging Unit are viable.

The only small scale paper mills that actually operate in Britain today are hand-made paper mills. In the Two Rivers Mill in Lancashire, R W Partridge was reported to be making a living in 1979, producing about 500 sheets a week, size 600 x 420 mm, of high quality 'art' paper from bought-in pulp. Peter Bower ran a hand-made paper workshop in St Albans, making 'art' paper from high quality recycled pulp. He and Bruce Glasser have been making paper on this scale for some time as a

part-time activity, and sell their papers for 40p or more a sheet. Both these paper mills (or workshops) however, rely on producing high quality papers from high quality materials for their financial viability, and could not operate economically using lower quality reclaimed paper as their raw material.

The Melbourne machines fulfil the criteria of small, cheap, equipment, but can they be operated in an economically viable way in Britain? The Melbourne 5 is theoretically rated to provide between 2,000 and 3,500 sheets per week. Sold at a similar price to hand-made 'art' paper, 40p a sheet for instance, would give a product value of £800 to £1,400. However, the paper produced by the Melbourne machine is not of the same quality as hand-made paper, particularly if post-consumer waste paper is used as a raw material. If the Melbourne was used to produce sugar paper, a low quality drawing paper used in schools, the weekly production of between 0.1 and 0.2 tonnes would only be worth £40 to £80. The latter figure could obviously not support one or two jobs; but if an intermediate value product, between 'art' paper and sugar paper, or a product mix to achieve this were aimed at, the Melbourne could feasibly become a financially viable concern.

(ii) Cellulosic insulation:

Cellulosic insulation is a loose-fill 'fluffy' material, produced from waste paper, usually newspapers. Its production involves shredding and hammer-milling the waste paper and the addition of chemicals to provide fire retardancy. It is installed by blowing or pouring it into place. It is generally considered to have good insulating properties and not to be toxic or a significant fire hazard.

Figures quoted by the US Department of Housing and Urban Development (1975) shows a better 'R' value for cellulosic insulation than for rockwood or glassfibre, as shown in Table 5.1. (R value is thermal resistance, and equal to 1/U value.)

Table 5.1 COMPARATIVE INSULATION VALUE OF CELLULOSE, ROCKWOOL AND GLASSFIBRE

Overall R-Value*	Inches of Loose Fill Insulation Material Required		
	Cellulose	Rockwool	Fibreglass
R - 11	3"	4"	5"
R - 19	5"	6"-7"	8"-9"
R - 22	6"	7"-8"	10"
R - 30	8"	10"-11"	13"-14"
R - 38	10"-11"	13"-14"	17"-18"

* R-Value (thermal resistance) = $\frac{1}{u\text{-value}}$

Source: US Department of Housing and Urban Development (1975)

Some debate has surrounded the questions of fire retardancy capability, attractiveness to vermin, and the possibilities of corrosion from added chemicals, of cellulosic insulation, and the criticism has been levelled in all three respects. However available literature on this subject is very sparse, and hence it is difficult to draw firm conclusions. Prevailing opinion though, seems to favour the conclusion that cellulosic insulation is not a hazardous material.

The Agreement Board (1977 and 1978) concluded in their preliminary report on Shelter Shield cellulose insulation, produced by Diversified Insulation in Scotland, that:

"the thermal performance of Shelter Shield treated cellulose fibre is equal to that of material presently used in this area of building insulation (such as glass or mineral fibre) and that installation of the treated cellulose fibre should not result in a significant increase in the fire hazard which exists in a normal loft situation."

This conclusion is supported by Rogowski and Sutcliffe (1980) of the Building Research Establishment in their work on fire performance in loft insulation materials.

Although a relatively new product in Britain, the use of cellulosic insulation in the USA is well established, with, according to Bendavid-Val (1978), over two hundred manufacturing plants, accounting for around 30% to 40% of the residential building market. The suitability of this technology to community-based production is summed up in this quote from a feasibility study of cellulose insulation production carried out by the Tennessee Valley Authority (1977):

"Because cellulose insulation is produced from waste paper that is treated with fire-retardant chemicals, the product can be produced and marketed by small, local, mills that require relatively low amounts of capital investment. Because the finished product

is very light and bulky, it is not economically feasible to ship it great distances, thus lending itself to local production."

Bendavid-Val (1978) carried out a study, for the Institute for Local Self Reliance in Washington, USA, of the potential for community-based business to establish themselves in the cellulosic insulation field. The report, introducing a cautious note, concluded:

"Our analysis of the available data about manufacturing cellulose insulation leads us to recommend that a community-based business should not attempt to manufacture cellulose insulation initially; instead, it should first establish itself as an installation enterprise. Manufacturing cellulose insulation requires an initial capital investment of as much as \$300,000 to \$500,000. This is a relatively high level of capital investment per job created - as much as \$25,000 to \$50,000 which may be too high for communities stressing job creation. In addition, a community-based enterprise may not be able to market the volume of output necessary for financial success. A small manufacturing plant can be forced out of business overnight if a large manufacturer with a built-in distribution network moves into the same market area. Furthermore, setting up a cellulose fabrication plant requires substantial technical and business skills: obtaining these skills, performing the necessary equipment and marketing research, and getting the equipment ready for operation will require a delay of many months.

"We recommend that a community-based enterprise begin operation by combining a cellulose insulation installation service with a recycling service. In the course of operating this business, staff members would develop a thorough knowledge of market and supply conditions that would serve as a sound basis for expanding into manufacturing, if they choose to do so."

Their analysis was based predominantly on the cost of turn-key plants (that is, complete equipment packages) assuming a minimum capital investment of around \$300,000, to produce 400 tonnes per annum, employing ten to twelve people.

Another feasibility study of small-scale cellulose insulation industry came to a different conclusion. Klein et al (1978) considered a 'medium' scale and a 'small' scale operation. The medium scale plant was a turn-key plant, costing \$150,000 for capital equipment and start-up costs to produce 3,500 tonnes per annum and employing eight people. The small scale plant was based on the Mid-Sioux Opportunity Inc plant, which was developed around agricultural equipment, in particular a corn-feed grinder, and produced 1,200 tonnes per annum, employing five to six people, for a total cost of \$50,000 (capital equipment + start-up costs).

Klein et al (1978) concluded that both the medium and the small scale plants were viable operations, with the smaller operation taking far less capital to start, employing more people per unit of product, but having a smaller profit margin. The medium scale, therefore, has some economic advantages, balanced against the smaller scale operation's

advantage of being easier to start, and promoting more local co-operation and self-reliance.

b) Glass

Household waste glass (cullet) can be either directly recycled to produce more glass containers, or used in the manufacture of other products, such as an aggregate in road surfacing; in building materials with cement or clay; with cement or resin in tiles; in reflective paints as glass beads; as abrasives in glass paper; and to produce foamed glass fibre insulating materials. There is extensive literature covering the research and application of these and other recycling opportunities for cullet, particularly in the USA where most of the work in this field has been done. Research papers on this subject are gathered in: the Proceedings of the Symposium on the Utilisation of Waste Glass in Secondary Products, New Mexico University (1973); the Proceedings of the Mineral Waste Symposium, US BoM (bi-annual, 1970). Reviews can be found in Bate (1976); Clough (1974); Thomas (1979); Breakspear and Heath (1977).

Although technically feasible in most cases, the economic viability of community-scale application of these cullet recycling processes is, as yet, largely unknown. One exception is the work carried out at University College, Cardiff, which has led to a process for converting glass containers to decorative floor, wall and working surface tiles, which have properties of high resistance to scratching and scuffing, are hard wearing and show good skid resistance. The glass is first crushed, classified by size, then mixed either with a polyester resin (80% glass, 20% resin), or with cement (40% glass, 35% sand, 15% cement) set in a mould, cured and polished. Any colour combination is possible, as it is easy to adhere pigments to glass pieces (surface coat), or

glass dust can be used to give single colour tiles. The mixture can also be set in plaster mould to make products such as soap dishes and pipe flanges.

Economic analysis by Wheatley (undated) has shown that the production cost per m^2 increases with decreasing capacity or size of plant. A plant capable of producing 7,000 tonnes per annum, or 300,000 m^2 of tiles would have required a minimum selling price (to cover costs) of £3.90 per m^2 in 1978, whereas a 700 tonne per annum plant would require £7.17 per m^2 . A capital investment in the order of £50,000 would be required for a glass/resin plant producing 700 tonnes per annum, employing 9 people. This is a capital investment per workplace of £5,500. Cement/glass flooring production laid, in situ, would probably be cheaper to establish.

Despite attempts by the Cardiff research group to secure industrial support for establishing a tile production business in Britain, nothing has emerged so far. However in Liege in Belgium, a firm called Mineral Products has developed the process into a business employing thirty people, producing resin/glass tiles for street paving and moulded products such as waste bins, lampposts and bollards, complete with the City's emblem.

The production of foamed glass from waste glass, described by the Midwest Research Institute (undated), seems to offer some potential for community-based manufacture. Ground glass is mixed with sewage sludge and fired to about 700° , when the glass softens and the sewage gasifies, creating bubbles in the glass. The resultant material can be made into blocks, and used as an insulating material. Glass fibre, or glass wool, insulating materials can also be produced on a small scale; MRI(undatedb)

USBOM (1972) and Industrial Recovery (1974) describe the process involved and give some information on the commercial potential.

c) Plastics

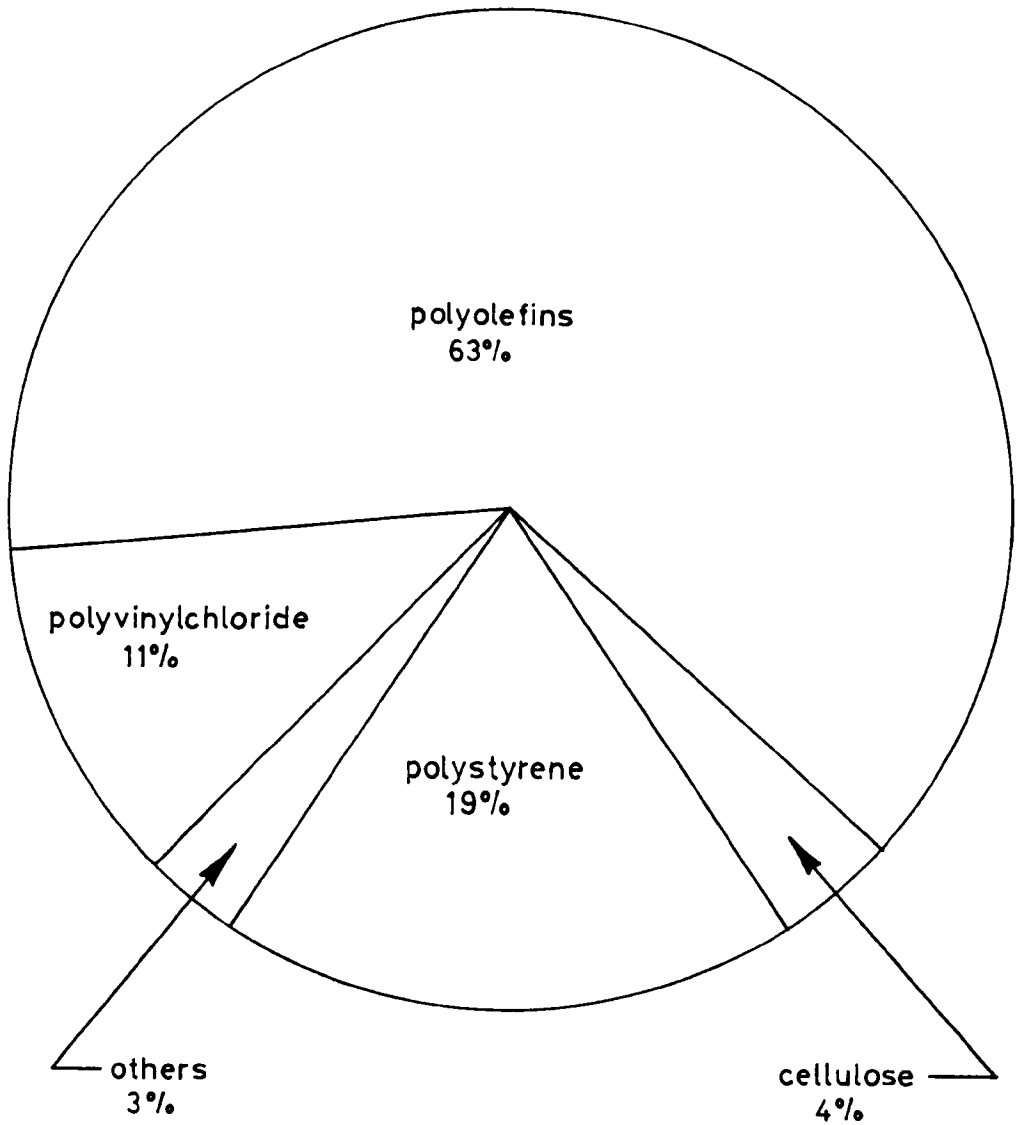
Waste plastics recycling is one area of recycling manufacture that is primarily carried out in small production units. Many plastics processors operate their own reprocessing or recycling machinery, or sell to specialised reprocessors who granulate, blend, extrude, cool, and pelletise the waste material, providing it is segregated into separate polymers. However, domestic plastics waste is a mixture of polymer types, as Fig 5.1 shows, and mixed plastics waste present many more problems for recycling.

Reprocessing a mixture of polymers where some polymers are incompatible can produce a material with few useful properties. Mixtures can, however, be adjusted if the approximate composition is known, and even domestic plastics wastes are of reasonably predictable composition, such that their properties can be predicted. Reprocessing of recycling mixed plastics wastes, however, is minimal at the present time. A number of processes that have been developed are discussed by Marshall and Shaw (1975), Thomas (1979), and Bollard and Vogler (1981).

Some of the earlier processes developed included:

- The 'Reverzer' process, developed by the Mitsubishi Corporation in Japan, and capable of handling all commonly used thermoplastics in any mixture, with a high tolerance to non-plastic waste contaminants. The mixed waste is injection moulded into a variety of shapes. Laport Industries Limited installed the Reverzer process at its plant at Widness to produce cable drums, fence posts and stakes under the trade name Analplas.

Fig 5.1 COMPOSITION OF PLASTICS IN DOMESTIC WASTE, 1970



Source: Bridgewater (1980)

- Reclamat International Limited (subsidiary of National Freight Corporation) which produced 'Tuftboard', a building board, from solid and film plastics waste.
- Kabor Limited produced a variety of products including furniture, agricultural building materials and pallets from polyethylene and waste paper.

These first generation technologies all suffered problems and many ceased operation after a few years. Improvements in mixed plastics waste recycling technology though has occurred, particularly in respect of developing cheaper equipment producing low-grade products, including:

- Remaker, a cheap (£25-50,000), simple machine which grinds mixed plastics waste, melts and moulds it into floor tiles, mud flaps and solid tyres.
- Regal process which converts crudely sorted plastics wastes into boards.

The capital costs in 1975 of plant to recycle plastics wastes varied from £15,000 to £150,000, with most equipment costing below £50,000 for an output of 30-50 tonnes per month (on average), according to Marshall and Shaw (1975). They studied the opportunities for thermoplastics reclamation in the NE of England, and carried out a financial viability analysis, based on a reclamation and recycling process for single polymer wastes. This showed a breakeven point of 30 tonnes per month, with 50 tonnes per month giving a reasonable profit. Capital investment was in the order of £20,000 to £50,000, and eight people would be employed.

Processing mixed plastics waste would present a different picture, but probably not dramatically so.

d) Metals

Metals in general have the best record for recycling in Britain, mainly due to our lack of indigenous raw materials for primary smelting and the ease with which most scrap metals, unless highly contaminated, can be recycled. Nearly all the metal in household waste is tin-plated steel cans and aluminium, and attempts to increase its recycling have tended to concentrate on improving reclamation techniques. Once reclaimed, these scrap metals are presently recycled in a few centralised plants; the tin-plated steel processed first in detinning plants, and then the steel resmelted in steel furnaces; and the aluminium to secondary smelters. Very little interest has been shown in Britain in developing a small scale recycling industry for these materials. Seldman (1975 and 1978b) reports that in the USA, where the quantity of aluminium scrap in household groups, such as Resource Recovery Systems (Connecticut) and the Recycle Aluminium Company (California) operate small aluminium smelters. Resource Recovery Systems' aluminium smelter cost in the region of \$5,000 in 1975 and handles around 2 tonnes per day. In this way they are able to increase considerably the value of the scrap aluminium that they reclaim. They have considered developing this further by manufacturing finished products such as window frames, from the recycled aluminium to improve their profitability.

A traditional small scale metals recycling activity is the blacksmith's craft. Once every village supported a blacksmith, whereas today, few working forges exist. At the Centre for Alternative Technology in

Machynlleth, Wales, they have established a blacksmith's forge to resmelt and cast equipment and components needed at the Centre.

5.2 RECYCLING OPPORTUNITIES FOR NEIGHBOURHOODS AND COMMUNITIES

This section attempts to match the scale of particular recycling processes with the size of 'community' to which it could be considered most appropriate. One measure of this appropriateness relates the recycling process to the size of the community by the quantities of waste used or generated by each. It is this measure that is used in this discussion; assuming a recycling technology or process to be appropriate to a particular size of community if that community could generate sufficient waste material, through a source separation reclamation scheme, for it to operate.

An analysis of waste products generated by neighbourhoods and communities is carried out in chapter 4, and the projected yields of recyclable materials from neighbourhood and community based source separation schemes, calculated, making assumptions about the likely household participation rates and yields of recyclable materials. These results are shown in Table 4.10. An attempt was made to match this information in Table 4.10 with the quantities of waste required by the recycling processes discussed in Section 5.1.3 and the results are shown in Fig 5.2.

Most of the small scale recycling technologies discussed earlier in this chapter could, as Fig 5.2 shows, only be supported by communities of 10,000 people or more. The Melbourne paper recycling plant is the only recycling technology discussed in this paper that could be considered appropriate to a neighbourhood scale, and the ITDG pulp packaging unit, the only process able to operate at a community scale. A population of

10,000 would be necessary to provide sufficient raw material from a source separation scheme for a 1 tpd paper recycling plant; 50,000 for a 5 tpd paper recycling plant, and 35,000 for the small scale cellulose insulation plant. All these technologies therefore appear most appropriate to district scale operation.

The other recycling processes discussed, including tile production from waste glass, mixed plastics waste recycling, and medium scale cellulosic insulation manufacture, would all need to draw on communities of more than 100,000 people to provide them with sufficient raw material; and up to 2½ million people in the case of small scale aluminium smelting.

This analysis considers only one aspect of relating a recycling process to the appropriate size of community; others might include demand for the products, the number of people employed, and the capital investment required. It provides a useful framework for initially assessing the appropriateness of a recycling technology to neighbourhood, or community development, in that it gives an indication of the size of the reclamation scheme that these waste recycling industries would need to draw on, using domestic waste as their raw material.

Only two of the recycling processes discussed appear in this framework appropriate as neighbourhood or community scale activities. These being the Melbourne paper recycling plants and the Pulp Packaging Units. It should not, though, be concluded that these are the only recycling technologies able to operate at a neighbourhood or community scale. This research has attempted to highlight some of the possibilities, and an extensive and comprehensive survey of opportunities for small scale recycling would require further research work. Neither does the

Fig 5.2 THE APPROPRIATE SCALE OF RECYCLING TECHNOLOGIES

Size of Community (by population)	Recycling process/equipment	Type of Waste Material Required by Recycling Process (amount in tonnes pa)
<div> <div>↑</div> <div>Neighbourhood</div> <div>↓</div> <div>↑</div> <div>Community</div> <div>↓</div> <div>↑</div> <div>District</div> <div>↓</div> </div> <div> <div>100</div> <div>1,000</div> <div>10,000</div> <div>100,000</div> <div>1,000,000</div> </div>	<div>Melbourne paper recycling plant</div> <div>Pulp packaging unit</div> <div>'1 tpd' paper recycling plant</div> <div>'2 tpd' paper recycling plant</div> <div>Small-scale cellulose insulation manufacture</div> <div>'5 tpd' paper recycling plant</div> <div>Medium-scale cellulose insulation manufacture</div> <div>Glass/resin tile production</div> <div>Mixed plastic recycling</div> <div>Small-scale aluminium smelting</div>	<div>-Paper (1.0)</div> <div>-Paper (30 +)</div> <div>-Paper (300)</div> <div>-Paper (600)</div> <div>-Paper (1,000)</div> <div>-Paper (1,500)</div> <div>-Paper (2,500)</div> <div>-Glass (560 +)</div> <div>-Plastics (500)</div> <div>-Aluminium (600)</div>

analysis in this chapter consider in any detail the financial viability of these processes. There is a need for further investigation of their operating costs profitability, and considering the wider aspects of the social costs and benefits of community recycling activities; these factors being as equally important as their technical feasibility.

CHAPTER 6

WASTE PAPER RECYCLING

It was concluded in the previous chapter, that the potential existed to develop waste paper recycling as a 'community'-scale activity. In order to explore this potential further, it is important to consider the context in which community-scale paper recycling would need to develop. This includes the historical development of paper-making and the paper industry in Britain, and the current situation regarding waste paper recycling in Britain. Section 6.1 provides a historical and technical background to paper and its manufacture. Section 6.2 explores briefly the steady decline in the British paper industry to its current low level of activity. A decline that has been accompanied by increasing use of waste paper as a raw material in the struggle to remain competitive. Section 6.3 looks at this use of waste paper in the British paper industry, and considers whether, and where, potential for increased use of waste paper exists.

6.1 THE MANUFACTURE OF PAPER

A considerable amount has been written about paper and its manufacture from both the historical and technical perspectives. Comprehensive references include Grant et al. (1978), Stevenson and Franklin (1969), Britt (1970), Clapperton (1952), Higham (1968), Halpem (1975), and Casey (1960).

6.1.1 Historical

Paper, which has been used as a writing material for nearly 2,000 years, is believed to have been invented in China by Tsai Lun in about 105 AD. The materials first employed in making it were old fishing nets, cloth

rags and plant stems. The quality, as indicated by samples in the British Museum, was high, comparable with hand-made rag paper produced today.

It took hundreds of years for the art of papermaking to spread to the rest of the world. In the 8th Century some Chinese paper-makers were captured by Arabs in Samarkand, and from here the craft travelled westwards to Egypt, to Morocco and then to Europe.

A substantial amount of literature is available documenting this early period in the history of papermaking; see Grant et al (1978), Hunter (1978), Hunter (1970), Leif (1978) and Weaver (1977). The earliest reference to a papermill in England can be traced to 1490, although paper had certainly been in use in the UK for nearly two hundred years by then, see Grant et al (1978), Coleman (1975) and Shorter (1971). In the early days in Britain, as in continental Europe, paper was made entirely from rags. Then, in the mid 18th Century experiments were conducted on the direct use of wide range of vegetable sources in papermaking. It was not, however, until the end of the 19th Century that wood pulp emerged as an important raw material. In the interim period, the supply of rags for papermaking was extended by the discovery of chlorine and the manufacture of bleaching powder enabling coloured cloth to be used.

Mechanisation in papermaking began in a significant way towards the end of the 17th Century with the development of the Hollander Beater for pulping. The first papermaking machine, though, was developed around 1800. Commonly known as a Fourdrinier machine, it was the fore runner of many present day papermaking machines. Shortly after the development of the Fourdrinier came the cylinder-mould machine. By 1830, about

half of the paper made in Britain was machine made.

6.1.2 Basic Principles of Papermaking

Paper is defined, by Grant et al (1978), as:

"A sheet or continuous web of material formed by the deposition of vegetable mineral, animal or synthetic fibres or their mixtures with or without the addition of other substances from suspension in a liquid, vapour or gas, in such a way that the fibres are intermeshed and bonded together. Paper may be coated, impregnated, printed or otherwise converted, during or after its manufacture, without necessarily losing its identity as paper."

A more commonly accepted description of paper would however restrict the fibres to cellulose fibres from plants, and the medium of suspension to water.

Although the size and character of the fibres obtained from different plants varies the papermaking process is principally the same for any cellulose fibre. Initially the fibres are immersed in water and fibrillated (bruised or crushed) so that the fibre walls retain increasingly more water. This causes the fibres to swell and to become gelatinous. The bruising process makes the fibres rougher so that they form a stronger bond when brought into contact with each other, though excessive fibrillation will lead to the deterioration of the fibres and to loss of strength. If the swollen fibres are deposited as a layer of pulp on a sieve or sieve-like screen, and allowed to dry, they will

intertwine and bond together (the fibres' gelatinised surfaces acting as a cement) to form a sheet of matted fibre of paper.

This is the basic principle of making paper employed in the paper making process which converts a raw material either plant matter, rags or waste paper, into finished paper. First the raw material must be broken down to release its cellulose fibres which are then fibrillated in water and form a layer of pulp on a mesh or sieve from which the paper is removed after having been allowed partially to dry. This basic process has remained the same since papermaking was discovered and is followed by all papermakers whether of hand-made papers or in highly automated mills capable of annual outputs of tens of thousands of tonnes. The machinery and equipment used in handmade paper mills and in industrial paper manufacture, however, differs considerably at both the pulping and papermaking stages.

6.1.3 Raw Materials

Paper is made from cellulose fibres which are bonded together to form a network. These fibres occur naturally in all vascular plants, being the basic structural components (the 'bones' or 'skeleton' of the plant which contribute to its rigidity. However, while many plants are capable of yielding fibre suitable for papermaking, the number which are considered capable of economic exploitation is relatively small. Even if the fibre is of a suitable size and character (which, in the case of many grasses containing too little cellulose, it is not), the plant from which it is extracted must be plentiful and easily replaced to ensure continuity of supply. Also the collection of the plant material, its transportation to a processing mill and the isolation of its fibres need to involve relatively low cost and ease of technical operation.

Many plants have been or are being used for making paper in different parts of the world. Jacob Christian Scaffer (1765) documented his experiments with papermaking from a variety of plants, including black poplar, sawdust, moss, spruce wood, rye straw, cabbage stumps, aloe leaves, peat and wasps nests. Nettle paper was one of a variety of papers used in the printing of 'A Historical Account of the Invention of Paper' by Matthew Koops (1890). Koops also used papers made from straw, wood and waste paper. More recently, the potential for straw pulping in Britain was investigated by the Paper and Board, Printing and Packaging Industries Research Association (PIRA) (1974b).

The more important vegetable fibres used for papermaking come from cotton, flax, hemp, jute, ramie, esparto, manila, sisal, straw, bamboo, bagasse, maize stalks, and deciduous and coniferous trees. All these are plants which yield sufficient quantities of fibre to make them economic for use in papermaking. Broadly, the materials derived from these plants fall into the following classes:

- (i) seed hairs - cotton;
- (ii) fibres found just beneath the stem's outer surface -
flax, hemp, jute, ramie;
- (iii) grass fibres - straw from cereals, bagasse from sugar cane,
maize stalks, bamboo;
- (iv) leaf fibres - esparto, sisal, manilla;
- (v) wood fibres - conifers and deciduous trees;

The primary raw material which best meets the criteria demanded by economic exploitation is thought to be timber. Timber also has a further advantage in that, by suitably varying the manufacturing process, a range of wood pulps can be obtained which will provide a wide range of

papers. Consequently timber has become the main raw material for papermaking, accounting for 89% of world paper consumption, according to FAO (1976). Wood pulp in one form or another is the most widely used of all fibrous raw materials for paper, and it seems unlikely that any major substitute will appear in the near future. However, experiments in the use of other plants for papermaking continue.

6.1.4 Hand-made Paper

Since the beginning of the 19th Century, the hand-made paper industry in Britain has decreased in volume considerably, to the 1976 production of 60 tonnes in two mills, according to Grant et al (1978). One of these, Hayle Mill in Kent is described by Cohen (1976) as employing sixteen people producing very high quality papers from cotton fibres. The raw material for hand-made papers is almost always textile fibres, usually, cotton, flax or hemp, either as virgin fibres or as rags.

The hand-made papermaking process usually begins with regrading, cutting and dusting the rags used as a raw material. They are then boiled, before breaking and beating to produce the pulp. In the 'breaking' operation, the cellulose fibres are crushed and ground in water so that the fibres are separated from each other while in a constant flow of clean water provided to carry away dirt and caustic residues. Breaking is followed by 'beating' where the fibres are crushed and fibrillated to increase their capacity for absorbing water, and to increase the potential area for contact between adjoining fibres when the paper is formed. In many hand-made paper mills, Hollander Beaters are used as both breakers and beaters. In these a heavy cyclinder, perhaps weighing half a tonne, rotates above a bed-plate. Metal bars on the surface of the cylinder grind the fibres between themselves and the bed-plate.

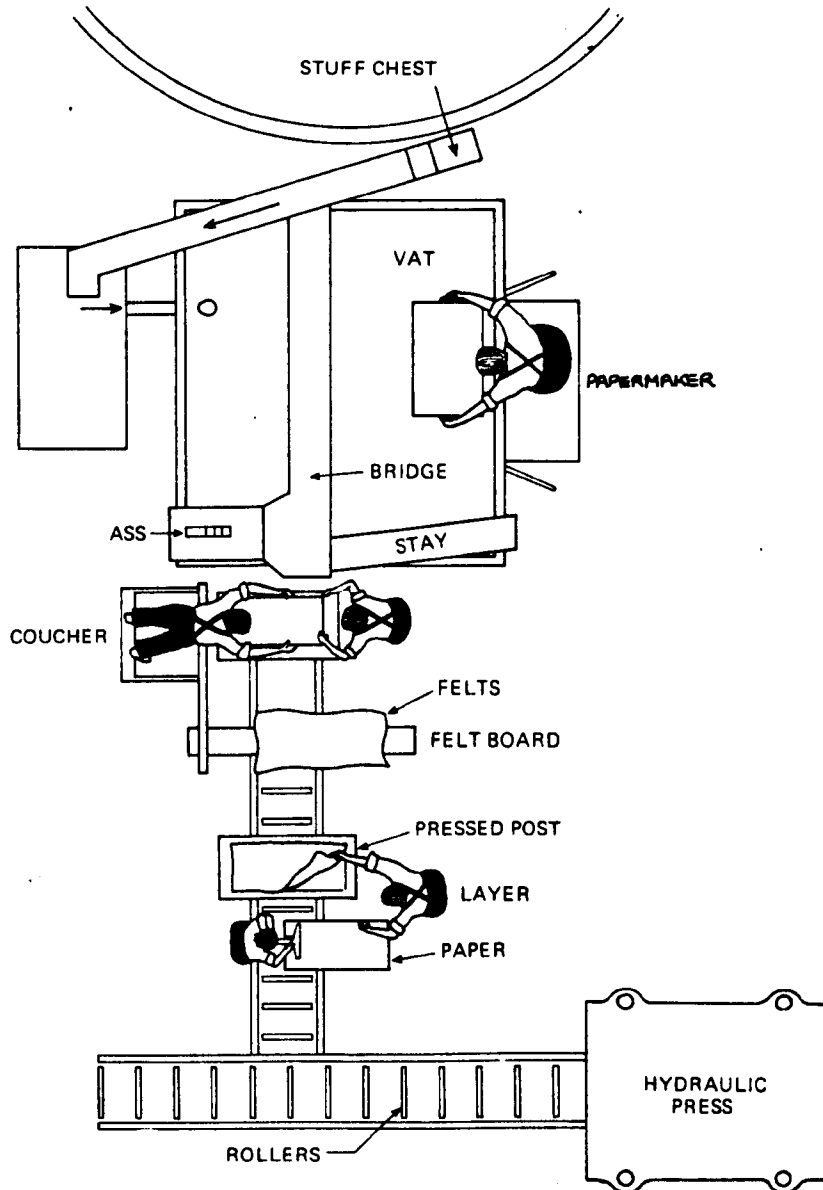
The gap between the cylinder and the bed-plate can be set in such a way that the degree of cutting (shortening) of fibres as opposed to crushing (or fibrillation) can be controlled.

Once the pulp leaves the beater its character is well fixed and it is almost ready for making into paper. After the addition of chemicals, such as size or dyes, the pulp, now referred to as stuff, is stored in the stuff-chest, from which it is diluted with water before passing into the vat, a rectangular tank usually fitted with an agitator and a steam pipe to heat the contents.

Sheets of paper are made at the vat by the papermaker with the aid of two moulds and a deckle. The mould is a rigid frame made of mahogany and covered with a fine wire mesh. Over this fits the deckle, another frame which governs the size of the sheet and its thickness. The papermaker dips a mould, with deckle, into the vat and lifts it out with pulp on it. As soon as it is lifted out water starts draining through, but the skill comes in throwing off the surplus pulp to give a sheet of the weight wanted. The mould is also shaken from side to side, helping the fibres to knit together, and to produce an even sheet.

The mould is then passed to the coucher, the deckle being removed on the way. The coucher, standing at the side of the vat, inverts the mould onto a pile of felts taking care all the time that no drips of water fall on the sheet as they would cause thin, round patches. The sheet of wet pulp remains on the felts and is then covered with another felt. This process continues until a pile of sheets has been built up, known as the post. The post of felts and sheets of paper are put into a press and much of the water is squeezed out. This is the start of a long drying and maturing process.

Fig 6.1 TYPICAL LAYOUT OF A HAND-MADE PAPER MILL



The wet sheets of paper are removed from the felts after pressing, and the pile of paper is sometimes pressed again. This is then usually dried in lofts, either on a large hessian or canvas tray, or hung over ropes of jute and cowhair (to prevent marking). Wads of 3-12 sheets are dried together. Drying lofts are often unheated, but well ventilated. In cold or wet weather some heat may be used to complete drying.

When dry, the paper will require further pressing to remove wrinkles and cockles introduced by drying. It may also be further processed by sizing, to reduce its absorbency, or by pressing between smooth metal plates to achieve a smooth surface. Further details of hand-made papermaking are contained in Grant et al (1978), Cohen (1976), Sweetman (1977), Studley (1978), Heller (1978), Barcham Green (1960) and (1971), Stevenson and Franklin (1969).

6.1.5 Industrial Paper Production

a) Pulping

Virtually all machine-made paper in Europe and North America is produced from trees. After felling, trees are cut into logs and the bark removed. This can be achieved by either rubbing logs against each other in large rotating drums, or by scraping; or by playing strong jets of water onto the bark surface. The bark can be used as an organic mulch, burned as a fuel in the pulping mill, or used as landfill material.

Once the bark is removed, the wood is pulped either by mechanical or chemical means, or both. Mechanical wood pulp is made by grinding wood logs on a grindstone revolving at high speed in a stream of water and the resultant pulp is sometimes called groundwood pulp. Alternatively, the logs may first be chipped into small fragments and the wood chips

defibred or pulped by revolving knives. Mechanical pulping is used chiefly for conifers with spruce being the preferred wood.

Mechanical pulp contains all the constituents of wood including the cellulose fibres, lignin and non-fibrous substances. The nature of the pulping process damages many of the wood fibres which, together with the impurities present, inevitably reduces their binding power. The resultant pulp has relatively low standards of colour, cleanliness and strength and has poor lasting qualities; it cannot be properly fibrillated or made to swell in the papermaking process and hence cannot produce a strong or durable sheet of paper. However, mechanical pulp papers are of adequate quality for many uses including newsprint and low-grade printing (particularly for magazine papers). They can also be used in writing papers, in fibreboard, in wrappings, and in tissues. Tissues with a high proportion of mechanical pulp are generally softer. Newsprint quality papers are major users of mechanical pulp and generally contain 75% mechanical and 25% chemical pulp.

One major advantage of mechanical pulping lies in the high yields of pulp it produces: 90-95% of the weight of cut, dry wood input to a mechanical pulp mill is converted to dried pulp. This compares very favourably with the yields of other pulping processes (see Table 6.1)

Table 6.1 PERCENTAGE YIELDS OF PULPING PROCESSES

Chemical	40-65
Chemical/Mechanical	65-95
Mechanical: groundwood	90-95
Mechanical: TMP	95 plus

Yields are expressed as percentages of the over-dry pulpwood input which are converted into oven-dry pulp.

Source: EIU (1975) and Grant et al (1978)

Thermomechanical pulp (TMP) is the result of another mechanical pulping process which fibrillates the wood at higher temperatures. TMP, according to EIU (1975), has an even higher yield than other mechanical pulping processes, (almost 100%) and is a stronger pulp that binds together better. Hence it takes print better than conventional ground-wood mechanical pulp.

The basis of chemical pulping is the use of chemical solutions to dissolve away those substances which naturally cement plant fibres together. In this process the fibres are separated with minimum physical damage and are mostly left whole. Consequently, the fibres of chemical wood pulp generally fibrillate better than those of mechanical wood pulp, and can be made to swell comparatively easily.

Chemical pulp processes are of two main types depending on whether the chemical solution used is acid or alkaline. Sulphite pulping is an acid process employing a solution containing calcium bisulphite and free sulphur dioxide. Spruce is the wood primarily processed in this way.

There are a number of alkaline based chemical pulping processes. The best known is the kraft or sulphate process which gives very strong papers typically used for strong wrappings or paper bags. Other alkaline pulping processes include the soda, lime and monosulphite processes. Alkaline chemical pulping is suitable for a variety of fibre sources; including non-wood fibres, and for hardwoods and for conifers such as pine which have a resin content. Yields from chemical pulping are generally the lowest achieved in pulping processes since part of the wood is dissolved and washed away during the actual process.

A variety of pulping methods which employ combined chemical and mechanical pulping have been developed, including the Neutral Sulphite Semichemical (NSSC) and Cold Soda processes. Not surprisingly, many of the characteristics of these methods combine those of pure chemical and pure mechanical pulping, and yields (as Table 6.1 shows) generally lie between those of the other methods.

The pulp produced by all these processes contains many impurities, and requires further cleaning, beating and refining before being made into paper. This intermediate stage between initial pulping and papermaking can take place in either the pulp or paper mill. Obviously in combined pulp and paper mills the distinction between pulping and papermaking is not important, but the vast majority of British papermaking is carried out in paper mills using bought in pulp, usually imported from Scandinavia or Canada. This pulp may be processed to different degrees of refinement, but in most cases some cleaning, beating and refining processes are required at the paper mill before the pulp is ready for making into paper.

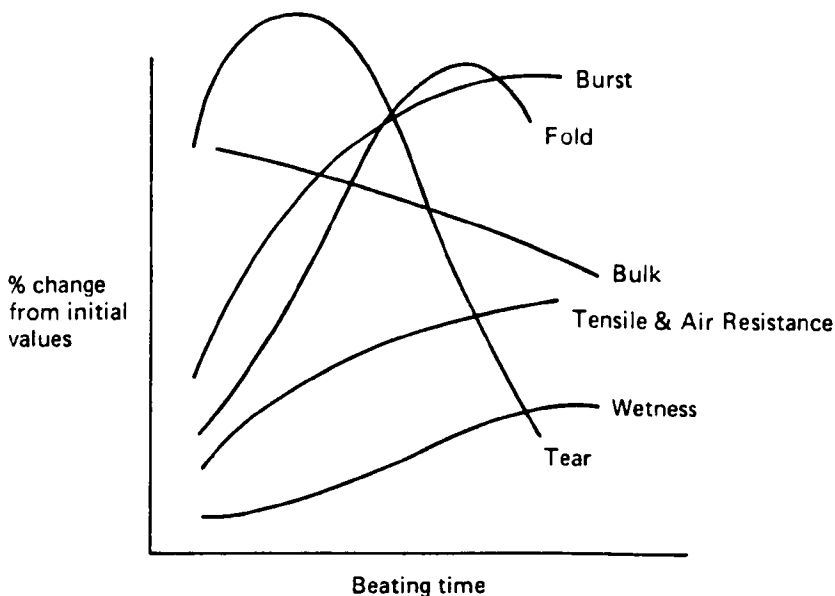
b) Papermaking

The first stage in the papermaking process involves cleaning and bleaching the pulp, which at this point contains many impurities, including bundles of fibres, knots and pieces of bark. Both mechanical screening and chemical methods (such as the addition of deflocculants to remove lumps of fibres) can be employed. If a white pulp is required, then the pulp is bleached, and this bleaching is often conducted in stages depending on the final colour desired. It may typically include the addition of chlorine gas to the solution of pulp in water, followed by the addition of caustic soda. Final bleaching may be achieved by treatment with sodium or calcium hypochlorite.

The pulp is then beaten in a beater or refiner to fibrillate the fibres so that they will intermesh to form a sheet. Since beating tends to shorten the fibres and increase their water absorption or degree of hydration, the amount of beating applied to a particular pulp plays an important role in the determination of the properties of the finished paper. In general, bursting strength, folding strength and tensile strength are increased by beating; whereas opacity is reduced.

Typically, blotting papers may be beaten for twenty to thirty minutes, bank notes for about eight hours, and high-class cigarette papers for up to twenty-four hours. Figure 6.2 shows a set of typical beating curves, showing the effect of increased beating time on a variety of paper properties.

Fig 6.2 BEATING CURVES



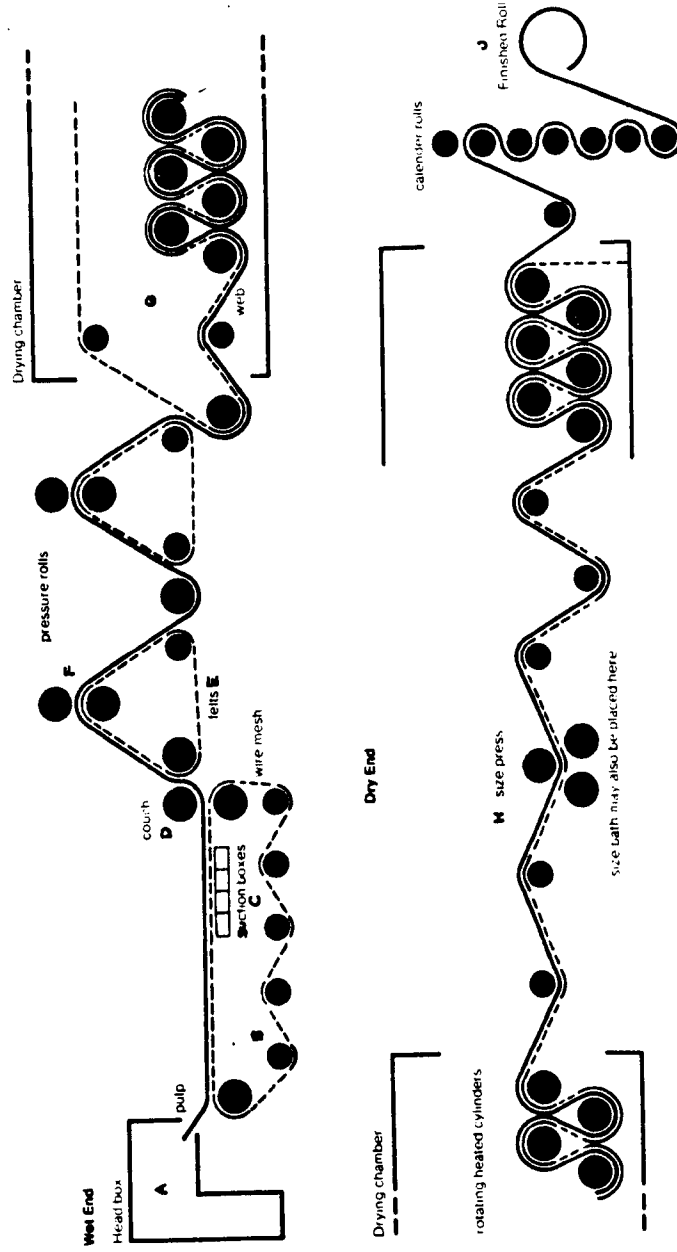
The characteristics of a finished paper not only depend on the properties of the pulp, but also on the loadings or fillers, sizing agents and dyestuffs or pigments added to the pulp, (see for example Browning (1977) and TAPPI (1958)).

Loadings or fillers are fine particles of mineral matter used to fill the spaces and crevices between fibres to smooth the surface of a sheet. The most common filler used is china clay (kaolin); others include mineral white (a form of gypsum), titanium dioxide, and calcium carbonate. Sizing a paper renders it more resistant to penetration by water. The most common sizing agent used is rosin and alum (sulphate of alumina); others include paraffin wax and petroleum resins and sodium silicate plus alum. Colouring agents may be added not only for coloured papers, but also to adjust the shade of white. Pigments are coloured loadings which coat the fibres; dyestuffs are added in solution to colour the fibres. In addition to these, wet-strength resins, wax emulsions and non-toxic fungicides (to prevent mould growth) may be added to the pulp or paper at some stage.

The pulp is then ready to be made into a sheet of paper. Basically this process involves three steps: rolling out the pulp, squeezing out the water and drying the finished product. Although straightforward in principle, a papermaking machine is generally a large, complicated and very expensive piece of equipment, (see Clapperton (1968) for further details).

Figure 6.3 shows the major parts of a Fourdrinier paper machine, the most common type of machine in use. Papermaking begins at the 'wet' end in the head box (A) when the pulp is projected onto a travelling wire mesh under controlled conditions of speed and quantity.

Fig 6.3 FOURDRINIER PAPER MACHINE



The wire (B) is an endless travelling belt of wire mesh which is shaken from side to side to help intermesh the fibres and to lose much of the water by drainage. Suction boxes (C) assist further removal of water. The wet mass of pulp, known as the web, is then picked up by the couch roller (D) and transferred to travelling belts of felt (E) on which it is carried through two sets of pressure rolls (F) to remove more water and to consolidate the structure of the web.

The 'dry' end of a papermaking machine starts with the drying chamber. A series of very large, rotating, heated cylinders (G) remove most of the remaining water, reducing the percentage of water present in the web from about 66% (when it enters the drying chamber) to 3-6% in the finished paper. Towards the end of the drying chamber, the paper may be passed through a tub of size and/or a size press (H) to give a high gloss finish while the paper is still wet. Immediately after the drying chamber the paper may be 'calendered' if a smoother finish is required. Calender rolls (I) are heated, pressured rollers which polish the surface of the paper before it is wound into a large roll (J).

6.1.6 Properties of the Finished Sheet

The properties of a finished sheet of paper or board depend on the kind of plant from which the cellulose fibres were obtained and the methods by which they extracted and processed. These various properties can be categorised as optical, absorptive and mechanical.

Optical properties, such as the whiteness and opacity of the paper, are determined by its fibrous structure (by the spacing between the fibres in the network) and by the degrees of bleaching and beating involved in the production process. Absorptive properties, that is the porosity and absorbency of the paper, also depend on the papermaking process

used. For instance, wood pulp for greaseproof papers is beaten for a very long time and, if compressed, forms a very dense translucent sheet which prevents the easy passage of grease, Wood pulp for paper requiring absorbency, such as do paper towels, is beaten only very lightly so that the fibres form a loose sheet with large spaces between the fibres into which water can rapidly flow.

Mechanical properties such as tensile strength, softness, lightness and flexibility of the paper, depend on physical properties. These result from the arrangement of the fibres within the sheet and their treatment during extraction and paper manufacture. For instance, for wrapping papers, where the main requirement is strength, strong brown kraft pulp is commonly used and bleaching is avoided because it tends to reduce strength and is normally unnecessary. Lower quality printing papers, on the other hand, contain appreciable quantities of mechanical wood pulp and, where strength is not a primary consideration, are sometimes bleached.

It is frequently impossible to produce all the properties which are required for a particular type of paper, because the attainment of one desired property often limits the achievement of another, and hence an improvement in the quality of one property is accompanied by a decrease in quality of the other. For example, an improvement in whiteness is usually accompanied by a reduction in strength and vice versa.

Consequently, the skill of the papermaker lies in producing a sheet of paper which exhibits the best compromise possible within the terms of the paper's property requirements.

6.1.7 Waste Paper Recycling

An increasingly important raw material in papermaking is waste paper. Waste paper can be pulped in a similar way to plants containing a cellulose fibre. In theory, the repulping process should be less time and energy consuming, because the waste paper consists of fibres which have been processed already. These fibres simply require to be released from their existing structure. Although in practise partially true, there are however two major problems encountered in waste paper recycling. First, the presence of ink and pernicious contraries (the name given to materials other than paper mixed in with waste paper such as staples, plastic coatings and glue) in the waste paper ensures that paper made from waste is not as clean as the original source material. Second, it is inevitable that individual fibres from waste paper will be damaged either through mechanical ill-treatment while being released from their former structure (eg, in the beating process), and/or through chemical dgradation (eg, in bleaching).

Pernicious contraries are those substances in or on paper and board which cannot readily be seen or detected in a waste paper sorting room or in the preparation room of a mill, and which will seiously interfere with or even ruin the manufacture of paper or board. Some fifteen categories are listed by the British Paper and Board Industry Federation (BPBIF) (undated). Naturally, producers using waste paper in their paper manufacturing processes prefer waste paper merchants to supply waste paper which has had at least the easily-identifiable contraries removed. Until comparatively recently, this was done manually by unskilled labour assisted by elementary separation techniques such as wire mesh tables, or by more sophisticated machinery such as vibratory conveyor belts or electromagnets. Because of the rising cost of labour

and the dirty and monotonous nature of the job, emphasis has moved away from manual separation towards the development of wholly mechanical separation of contraries from waste paper.

Neither manual nor mechanical sorting can remove all the pernicious contraries, especially those which form an integrated part of the paper product when sold (such as latex, asphalt, thermoplastic adhesives, wax and resins). Consequently, while papermakers who use waste paper require their raw materials to have had the obvious pernicious contraries removed, they have to rely on their own machinery and their own labour force to remove as many of the remaining contraries as possible.

Very little special equipment is required to process the highest pulp substitute grades of waste paper. Neither is much processing necessary for lower grades if a low quality product is desired. However, in most recycling plants a number of processes are involved in the preparation of waste paper, including pulping, classification and purification, the removal or dispersion of contraries, and possibly de-inking, cleaning and bleaching.

Two opportunities to remove contraries arise while waste paper is actually being pulped. A wire or ragger (simply a length of rope or wire) can be immersed in the pulper and gradually winched out. The revolving motion of the contents of the pulper spins pieces of wire, string, plastic sheeting, rags and similar material into a rope and they are thus removed. In addition, a junk trap or junker is usually incorporated at the bottom of the pulper to remove heavy objects such as coins and other pieces of metal.

The waste paper pulp also known as the stock, and now of a consistency of about 3-6% fibre and 94-97% water, then undergoes a number of cleaning and screening processes. These fall into two groups: 'thick stock' cleaning and screening which occurs directly after pulping, and 'thin stock' cleaning and screening, which is the final method to be employed in improving the cleanliness of the pulp. Both involve the same basic processes - centrifugal cleaners, pressure screens and vibrating screens - to separate contraries by size and density differences. Heavy materials and large items such as paper clips, pins, glass splinters and staples, and also plastics (before they break down further into smaller pieces) are removed at the thick stock stage. The pulp may then undergo deflaking, refining, dispersion and/or de-inking before the final thin stock cleaning and screening at a lower consistency than before to remove finer contraries.

In general, complete defibrisation does not occur at the pulping stage and hence clumps of fibre are still present in the stock even after cleaning and screening. These must be broken down before the pulp is acceptable for papermaking. With virgin pulps, declumping would occur in the refiner since a reasonable degree of work must be done on these fibres to make them suitable for papermaking. Waste paper fibres have been previously refined and thus the degree of refining in recycling operations must be carefully controlled to avoid excessive hydration and the breaking down of fibres into short fibres or 'fines'.

Deflakers have hence been developed to break down fibre bundles without affecting the individual fibres. A degree of refining may follow deflaking if the properties of the fibres need to be altered.

These are the basic processes found in any waste paper preparation system. For high-quality reclaimed fibres, these steps are sufficient,

but for lower quality waste paper, the pulp produced at this stage will not, according to Paper (1975)a, be clean enough for many purposes other than the manufacture of low-grade packaging papers and boards and building boards. The pulp will probably still contain tar (asphalt and bitumen), wax paraffin, wet strength resin and ink. Unless removed or effectively dispersed, these contraries can ruin the finished product, forming black spots or greasy marks in the paper.

Tar and wax are difficult to remove, but they can be dispersed at high temperatures (up to 150°C). Dispersion of inks in lightly printed paper is often used as an alternative to de-inking, and produces a homogenous, lightly tinted sheet.

When either highly printed waste paper such as newspaper is involved, or the pulp is to be included in the furnish of higher quality papers such as some printing and writing papers, dispersion may not produce a white enough pulp and de-inking is necessary, according to Paper (1975)b. The two major methods used are the washing of the pulp on screens and a process of floatation where air bubbles collect ink and fillers, separating them from the fibres and forming a foam on the surface. Other methods have been, and are being, developed.

Although technically well developed, de-inking has not received wide application except in the production of newsprint and, in some countries, of tissues. The reasons for this are economic; the operating costs are higher than for most other waste paper processing operations, not only because de-inking is a costly process in itself, but because it also creates large volumes of effluent which are expensive to treat.

Bleaching may also be used to whiten the recycled pulp and is often employed as a adjunct to de-inking since with de-inking alone a quantity of ink will remain in the pulp. However, bleaching creates an additional pollution problem and thus additional expense.

Despite all this varied and complicated equipment some contraries will remain in the pulp. For example, non-water soluble adhesives generally cannot be dealt with effectively.

The second problem of using waste paper as a raw material - loss of fibre strength - is also important. It has been noted earlier that when wood fibres become separated during pulping the cellulose swells, and the extent of this swelling determines the paper strength when the fibres shrink and bond together. Waste paper fibre will be weaker after pulping, the degree of weakness depending on the number of times the fibre has been pulped before. On average, waste paper fibres are shorter than virgin fibres and less swelling takes place, so that the bonding is weaker and the final paper strength less.

Although paper and board made from recovered fibrous material may not be as strong as that made from virgin pulp, it has many advantages in the manufacture of certain types of paper and board products; for example, in the manufacture of household tissues, blotting paper, wallpaper and even some printing papers. This is because, as the number of repulpings of the fibrous material increases, the caliper or thickness of the finished product will also increase, the product becoming less dense and more porous. These are properties required for blotting paper, toilet and household tissues and, to some extent, for printing papers, because if they are porous they can more easily absorb printing ink.

In summary, it can be stated that a sheet of paper made from waste paper will be as weak and, without special treatment, as dirty as the original paper from which it is made, and usually weaker and dirtier. This emphasises the point that a paper made from waste fibre can, at best, only be as good as the quality of the waste paper input. Also, the previous manufacturing history of the waste paper input will have an influence on the properties of the recycled paper. However, while it is generally accepted that recycled paper has less fibre strength than paper made from virgin pulp, Childer and Howarth (1972) suggested, as a result of research carried out at the University of Manchester Institute of Science and Technology in the Paper Technology Department, that some fibre characteristics such as tear strength and opacity might improve after a number of recyclings. But to maintain strength in paper which is being recycled repeatedly, it is necessary to add a proportion of virgin pulp or new waste paper.

Further details regarding waste paper recycling can be found in PIRA (1974) (a & c), Massus (1974), Paper (1973^{a,b}) and (1975a).

6.2 THE PAPER INDUSTRY IN BRITAIN

Over the past twenty years or so, the importance of the British paper industry has declined. In 1962 Britain was the fourth largest producer of paper in the world, but had fallen to be the tenth largest by 1973. In 1974 the British paper industry produced 4.6 million tonnes of paper and board in 180 mills. Between 1965 and 1975 employment in the British paper industry dropped by one-third, to about 70,000 people.

Over the ten year period from 1964 to 1974, imports of paper to Britain increased from 2.15 to 4.1 million tonnes per annum, and fell again to 3.9 million tonnes by 1979. Domestic production remained virtually

static from 1964-1974 rising only from 4.5 to 4.6 million tonnes; falling to 4.2 million tonnes in 1979. The result has been a fall in the percentage of home-produced papers on the British market. In 1964 68% of all paper consumed in Britain was home produced; by 1979 only 54% was consumed.

Historically the British paper industry has relied heavily on supplies of imported wood pulp. The United Kingdom's resources of timber are only sufficient to provide about 8% of the raw materials used in paper. This use of imported raw materials put the industry at a cost disadvantage compared with forest-rich countries. Imported pulp has to be dehydrated before shipping to minimise the transportation costs, and the process has to be reversed before the pulp can be used for paper-making. Because of this additional processing, the cost of raw materials in British produced paper is proportionately higher than in countries such as those of Scandinavia and Canada.

British membership of the European Free Trade Association (EFTA) during the 1960's removed tariff barriers and allowed the Scandinavian paper and board to penetrate the British market with low priced, high volume papers. The British paper industry has produced low profit margins on the whole since the 1960's and has suffered from a lack of investment in new plant and machinery.

The direct effect of these factors, together with the dramatic rise in wood pulp prices dating the early 1970's and the shortage of pulp supplies (caused by primary producers integrating vertically, has been to make British papermakers concentrate on two areas of production; high quality speciality papers, and waste paper based varieties of paper and board.

Between 1963 and 1979 the consumption of waste paper by the British paper industry increased from 1.4 to 2.2 million tonnes. With a virtually static production output, the utilisation rate of waste paper (total consumed waste paper as a percentage of total paper production) rose from 34.1% to 52%.

6.3 WASTE PAPER RECYCLING IN BRITAIN

In 1979, according to statistics in OECD (1980), the British paper industry used 2.2 million tonnes of waste paper, representing a 52% utilisation or recycling rate. That is, 52% of the raw material used in paper produced in Britain that year. The recovery rate of waste paper as a percentage of total paper consumed in Britain in 1979 was 28.5%.

Obviously 100% reclamation of waste paper cannot be attained. The maximum theoretical limit to recovery of waste paper as a percentage of total paper consumed was estimated by Massus (1974) to be 79.5%. The other 20.5% comprises papers which are destroyed in use (such as cigarette papers, domestic and sanitary tissues and papers which are incinerated at their place of use), papers taken out of the paper stock indefinitely (such as books, wallpaper, building boards and electrical capacitors) and papers which are combined with other materials in composites in such a fashion that they cannot be recycled. The practical limit to the recovery rate, however, is thought to be slightly less than the theoretical maximum. The British Paper and Board Industry Federation (BPBIF) (1976) estimates that 69% of the total paper and board consumed in the UK is available for economic recovery. Only 28.5% is actually recovered, so there is still a considerable potential for increased recovery of waste paper.

Restraints limiting the maximum utilisation rate (that is, the amount of waste paper used as a percentage of total raw materials) of waste paper in the UK are imposed not by waste availability but by fibre length, quality of fibre and the presence of contraries in the reclaimed waste. The overall utilisation rate in 1973 was approximately 44%. Two studies undertaken in 1974, PIRA (1974a) and Massus (1974), attempted to forecast possible increases in the utilisation rate of waste paper in the British Paper and Board Industry. The PIRA study reached the conclusion that maximising the use of waste with the then currently available technology, would probably increase the utilisation rate to 58%. Massus (1974) made two assessments; it forecast that by 1980, given the normal evolution of technology, a utilisation rate of 56% was likely, and that with a special research and development effort this could be raised to 63%. The utilisation rate in 1981 was almost 58%. Evidence suggests that it could now be higher, and that, as concluded by OECD (1979), the socially desirable level of recycling is also likely to be higher.

About one-third of the waste paper used in the British paper industry are classified as the higher quality grades; these being mainly waste from paper convertors (such as from box makers) and that derived from other industrial and commercial sources. Table 6.2 shows the usage of different grades of waste paper in the industry for 1973. The lower grades of waste paper consist of post-consumer wastes, in particular domestic and retail trade waste. The main constituents of these grades are packaging board (cardboard), newspapers and magazines, kraft wrappings and sacks and mixed waste paper. It is in these grades that the most potential for increased recovery exists. Low grade paper is nearly all used in packaging products, but it can be used in producing other papers, although there are some technical and economic problems

which must be considered. If a significant expansion in waste paper recycling is to occur, the inclusion of lower grade waste in products other than packaging must play an important role.

The higher grades of waste paper are virtually fully exploited with as little as a 3.5% increase estimated as realisable. However, no detailed analysis is available of waste arisings, and there may be greater potential than is thought for the increased collection of some higher grade wastes from commercial and large retail sources. It is generally agreed that the greatest potential for increasing the collection of waste paper rests with the lower grades arising from domestic and retail sources, and currently collected as municipal waste by local authorities.

Table 6.2 WASTE PAPER USE IN THE UK PAPER INDUSTRY, 1973
(in thousands of tonnes)

Paper & Board Waste Paper Grades	Print- ings	Packaging Papers for Corrugated Board	Other pack- aging Papers	Boards	Other Papers and Boards: Domestic and Industrial	Total
Mixed Papers	6	475	17	729	19	1,246 61%
Corrugated board waste kraft	-	201	51	161	5	418 21%
Newspapers brochures directories	70	34	1	107	6	218 10%
Tabulating cards	17	-	7	3	10	37 2%
listings	63	-	34	18	19	13 6%
Printer's waste	156 7%	710 35%	110 5%	1,018 50%	59 3%	2,053 100%
Total Waste Paper						
Paper & Board Production	1,730	856	320	1,172	536	4,614
Utilisation Rate	9%	83%	34%	87%	11%	44%

Source: Massus (1974)

Packaging papers and boards consume 90% of waste paper in 50% of the production of the British paper industry. Therefore, the products in which any significant growth in the use of waste will occur are most likely to be other paper products including newsprint, printing and writing papers, and tissues and hygienic papers. A growth in the use of recycled fibres in these grades, however, must be accompanied by a drop in the quality expected of these papers if the potentially available lower grade wastes are to be absorbed.

To obtain a clearer picture of where recycling can feasibly be expanded it is useful to look in more detail at some specific product groups.

6.3.1 Printing and Writing Papers

Printing and writing papers cover a wide range of products from very high quality papers to paper for jotting pads and school exercise books. Also included are coated and uncoated book papers, mechanical printing papers, duplicating papers and papers for internal office memos. Obviously the same criteria for quality and performance cannot be applied for all these papers. It is difficult to see where the use of waste paper in the high quality end of this group can be expanded, except perhaps by using a greater proportion of the very high quality pulp substitute grades. However, for other printing and writing papers it would certainly seem possible to increase the recycled fibre content. Printing papers currently account for nearly 20% of the UK consumption of paper products, but only contain on average 9% recycled fibre.

(MRI)

Midwest Research Institute^A (1973b) concluded that the most promising end uses of de-inked waste paper pulp in this area were in mechanical papers generally, uncoated book papers and writing papers. The waste paper input considered was mainly convertors' waste and office waste, and

the report found that it was technically feasible to produce a good sheet of paper using 100% waste paper, although the quality was found to be more variable than with virgin pulp based papers.

Despite the considerable potential for increased use of the relatively high grade waste paper pulps in printing and writing papers, there exist limitations in the supply of these grades. Greater expansion in the use of recycled fibres will come as technological developments allow products like printing and writing papers which currently incorporate these higher grades to utilise lower grade papers. American experience has shown that the application of low grade waste papers is technically feasible, and experimental papers based on recycled domestic mixed waste have met normal paper specifications.

Massus (1974) argues that there are excellent opportunities for increasing the use of waste paper in EEC produced printing and writing papers, and suggests a utilisation rate of 28.5% of recycled fibre as feasible for this product group.

6.3.2 Newsprint

Newsprint produced in Britain contains on average 19% recycled, de-inked fibre. Individual newspapers can vary from 10%-80%, although the higher figure is not achieved in regular production.

It is technically feasible to produce 100% recycled newsprint from de-inked waste newsprint. MRI (1973b) cite some tests made by the American Newspaper Publishers Association Research Institute on samples of newsprint produced from virgin wood pulp and samples from 100% recycled fibres showing them to be technically comparable even on factors of tear strength and brightness.

6.3.3 Tissues

It is difficult to draw a conclusive picture of the opportunities for recycled fibres in tissue production when even figures for the current utilisation rate are not readily available, although known to be low. MRI (1973b) conclude that there are essentially no technical limitations to the amount of recycled fibres which can be used in tissue manufacture. However, quality considerations ensure that usually only pulp substitute and high quality, de-linked grades are acceptable furnishes, and the use of post-consumer waste paper is very low in tissue manufacture in the USA (only 11%). The current figure for Britain was not available.